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ASPECTS OF THERMOREGULATION IN BATS

BY WILLIAM G. REEDER AND RAYMOND B. COWLES

In so far as fairly extensive, but still incomplete data permit, it seems clearly apparent that for the majority of animals short periods of overheating constitutes a much greater hazard than does an equivalent degree of cooling. A rise of only a few degrees above the optimum temperature is almost immediately fatal, whereas a much greater fall in temperature merely retards metabolism or leads to cold narcosis or hibernation (Cowles, 1939, 1940, 1944). As shown by Cowles (1945*a*, 1945*b*, 1949, Cowles & Burleson, 1945), a more subtle, but far greater over-all danger lies in the susceptibility of the male germ plasm to non-lethal degree of somatic heating.

Overheating the somatic tissues results in the death of the individual organism. Of greater importance, however, is the long range danger which lies in the fact that in all known instances, prolonged exposure to moderate, apparently harmless heating, produces total or partial sterility in the male animal, and this sterility may be transient, seasonal, or permanent, depending on the organism and the intensity or duration of the heat exposure. As far as is known, the females are less affected by this germinal intolerance than are the males.

It is obvious that both the somatic and particularly the germinal consequences of inadequate cooling or overheating are exceedingly important and thus it follows that, because of the narrow margin of safety between optimum temperatures and the effects of heat damage, there must be excellent control of temperatures at the upper threshold of danger.

In most animals, especially those capable of true flight, the body temperatures during times of activity are very close to the maximum heat tolerance of the somatic tissues. This probably results from the increase of neuromuscular celerity associated with higher tissue temperature, a condition which would presumably confer selective advantages in competition for mates, food, and the avoidance of enemies. Since individual survival may be a result of speed-promoting high temperatures, natural selection would appear to favor survival of those individuals having temperatures nearest the thermal danger point. Thus the importance of high temperature thermoregulation and the associated heat dissipating mechanisms is apparent. The critical significance for the entire body and most especially the male generative tissues can scarcely be exaggerated.

Bats were chosen for investigations on this problem of heat dissipation be-

cause they comprise one of the two broad groups of vertebrates capable of true flight. All Holarctic Microchiroptera which have been investigated have been shown to be hemipoikilothermic, that is, the temperature of the individual essentially varies with that of the environment, but when activity is to take place, thermoregulation at optimum temperature is possible, at least within certain limits.

The experiments of Burbank and Young (1934), Eisentraut (1934), Pearson (1947), and Reeder (1949) have shown that during daily and seasonal periods of lowered metabolism the internal temperatures of bats closely approximate those of the environment. However, these data have not shown the rate at which internal temperatures can follow or lag behind the ambient temperatures.

In order to obtain information on thermoregulation and heat dissipation, bats of two species were suspended by threads in a chamber, the temperature of which could be closely controlled. The wings could be moved freely in any direction, and almost all body movements natural to a suspended bat were possible. To record temperatures, two copper-constantin thermocouples were used, one to indicate the temperatures within the chamber, or the effective environmental temperature, the second to record the rectal temperatures of the animal. The bats were suspended in the chamber, the thermocouple inserted rectally, and the mechanism of the refrigerator was set for its greatest cooling. At half minute intervals, ambient and body, i.e., rectal, temperatures were recorded. After reaching the lower equilibrium at about 5 degrees centigrade, the heating unit was started, eventually raising the temperature to slightly more than 40 degrees centigrade. The experiment was repeated with several freshly collected specimens of each of the two species tested.

The animals used in the experiments were collected in the Riverside Mountains, Riverside County, California, and transported to the laboratory under lowered ambient temperature. The body temperature was then allowed to come to equilibrium with the environment before placing in the system.

The results shown in Figures 1 and 2 are each average trials, using *Myotis velifer*, and *Macrotus californicus*, respectively. When placed in the apparatus the animals were in an active condition. This is reflected in the thermal differential shown at the start of experimentation. Due to variation in the rates, the graph time factor obtained for the two species cannot be compared directly, although the degree of thermal change is comparable. The results shown in the figures, therefore, shall be analyzed separately.

Figure 1, illustrative of thermal reactivity in males of the bat *Myotis velifer*, indicates that throughout long periods the rectal temperature of the animal follows, with a slight thermal lag, the variation of the ambient temperature. The amount of lag ranges from 8.1° C. at the beginning of the experiment, to 0°C. where the temperatures are equal at the beginning of the heating process, then increases to 4.2°C. as the environment is again warmed. The reactions of the various individuals of this species tested were very similar. Therefore, description of the activity of one animal under varied thermal conditions will be sufficient.

As the animal was placed in the apparatus, it was struggling to escape and was breathing very rapidly. As the restraining threads were attached to the feet, and the thermocouple inserted, a series of wing flappings was initiated. The

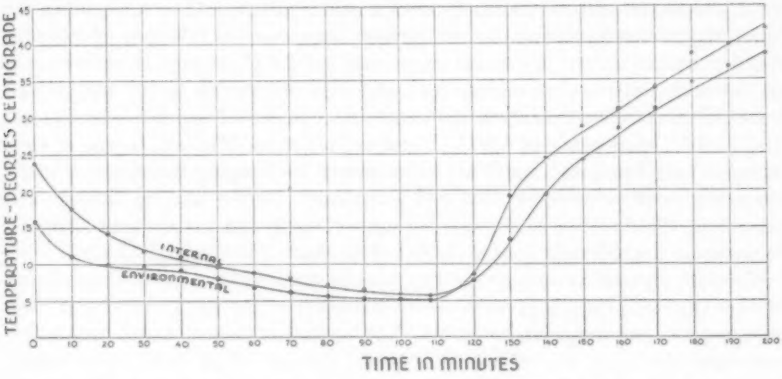

FIG. 1.—Illustration of the variability of rectal temperature in the bat, *Myotis velifer*, male, during a period of change in environmental temperature.

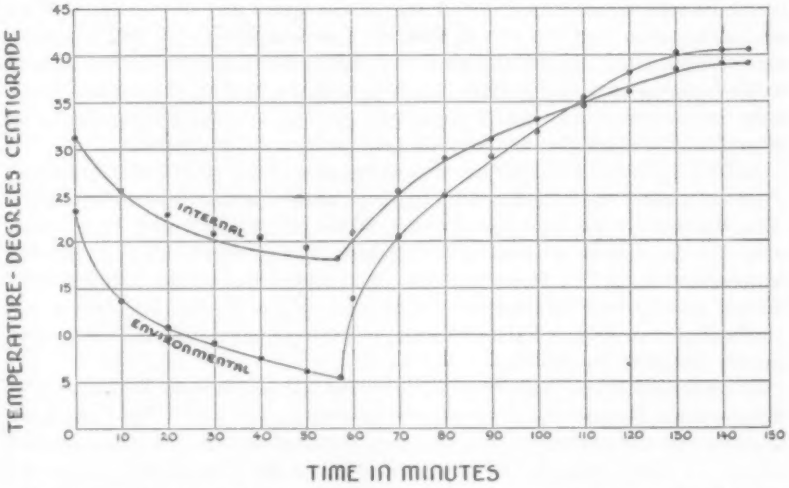

FIG. 2.—Illustration of the variability of rectal temperature in *Macrotus californicus*, female, during a period of change in environmental temperature.

membranes were not outstretched, however, but were held close to the body. The wing movements were rhythmic, being about two per second. As the rectal temperature dropped to about 13.0°C., the wing beats gradually slowed and

became arhythmic until, at 12.6°C., there were no apparent body movements except for slow breathing, approximating 30–40 respirations per minute. At this temperature, the animal made a few futile escape attempts, but the body activity was slow and ineffective, and soon ceased. Down to 10.0°C. a very slow, awkward movement, not unlike those of a cold reptile, could be initiated in the animal by violently jarring the refrigerator. Responses to this type of stimulus could be induced down to a rectal temperature of 5.8°C., though the movements at this temperature were minute and very slow. Shivering of the test animal was noticed at but two points as the temperature in the refrigerator was reduced, first at 9.5°, then again at 5.8°C., rectal temperature. The action was in each instance very brief, and could not be detected as changing thermal conditions when the results were later analyzed graphically. As the heating element was turned on, the direction of thermal lag was reversed, and the ambient temperature almost immediately became higher than that of the animal's body.

The first signs of voluntary activity became evident at a rectal temperature of 11.7°C., when the wings were slowly stretched to their full extent and then retracted. As the temperature within the chamber increased, there were a few very brief shivering movements by the test animal. Most of the movements, however, were of the large skeletal muscles, and, though sluggish, they were smooth and coordinated. From 12.9°C. up to 25.8°C., rectal temperature, there was almost constant muscular activity which, while still very slow at the lower thermal levels, became rapid and efficient at the upper part of this range. Wing movements were made, as before, with the fingers close together and the membrane undistended, though the arms were held extended, not retained close in to the body as when the animal was very cold. At 25.8°C., the motion of the body was reduced, the animal apparently resting. Breathing appeared to be intermittent, though this was impossible of positive determination.

At 30.2°C., rectal temperature, muscle reactions were rapid and coordinated when the animal was stimulated by jiggling the refrigerator or pounding on the door. Respiration rate was approximately 60 per minute. Voluntary body movements for the purpose of releasing the bonds on the feet were made at an internal temperature of 32.9°C. The wings were not outstretched at this thermal level, though an apparent attempt at cooling was evident by the cupping of the proximal portion of the wing membranes, which were fanned at a rate of approximately 40 beats per minute.

The respiratory rate was found to be about 100 per minute. The struggling of the animal became violent at a rectal temperature of 35.9°. The wing membranes were somewhat expanded, not being stretched outwardly to their greatest extent. At rectal temperature 37.0° a fanning of the outstretched wings was initiated. This movement, in the face of still rising ambient temperature, served to begin a leveling off of the internal temperature. The fanning was evidently acting as a mechanism for passing large amounts of air very rapidly over the flight membranes. The leveling of the curve is not adequately illustrated in the figure, owing to the fact that its appearance is obscured by the size and numbers of the units used.

The stress of the mechanical system and the length of time involved in changing the air temperature within the refrigerating unit undoubtedly lowered the resistance of the test animal. After 14 minutes of rapid fanning of the fully-opened membranes, the animal suddenly collapsed. This happened in each case where, as in this experiment, the animals were maintained in the system for a long period of time. The point of collapse was about the same, being between 37.8° and 39.0°C. The bats were then removed from the apparatus, after which they, in each case, died. Unfortunately, in no case was it possible to leave the animals until they produced the vascular engorgement which will be discussed later.

In *Macrotus californicus* the test animals were all females. As is often the case, the colony from which the experimental animals were obtained consisted of only one sex. The experimental results obtained from a similar test made upon three individuals of this species show a somewhat different pattern of reaction to varying temperatures than did the *Myotis*. From room temperature, 23.2°C., the refrigeration unit was set for maximum cooling. The cooling was continued until the unit came to equilibrium at 5.7°C. The heating unit was then set in operation, thus slowly raising the temperature of the chamber to 40.8°C., where the system again came to equilibrium. Inspection of Figure 2, and comparison of this with Figure 1, will show considerable difference in reactivity. One factor which makes proper correlation difficult, however, is the more rapid temperature changes used in the experiments on *Macrotus*.

The thermal lag shown by this species is much greater than in *Myotis*. It ranges from 6.0°C., at the initiation of experimentation, to 12.3°, when the environment is at maximum coldness. During the heating process the environmental temperature rises more rapidly than does that of the animal, and they become identical at 32.8°C., after which the ambient temperature continues to rise at a greater rate than that of the bat. Both temperatures reach equilibrium after 130 minutes in the system, the differential here being 1 to 2°C.

As the ambient temperature was lowered from 23.2°C. the internal temperature of the bat decreased, despite the constant struggling of the animal to free itself from its bonds. As its body temperature fell to 26.4°C. the animal became quiet, showing no movement except normal respiratory contractions. The wings were held close to the body, apparently in a reflex action that would effectively retard loss of body heat. At 24.3°C. the wings were relaxed slightly and a rapid vibratory shiver was initiated. The shiver appeared to be of constant frequency and intensity and occurred uniformly over the entire body. At 21.5°C. internal temperature a last attempt was made to escape, at which time the shivering was replaced by coordinated actions of the large muscles of the body. The legs were alternately flexed and extended, causing the animal to swing back and forth. This process continued for nine minutes and caused a slight rise in body temperature over that period.

As the struggling ceased, the shivering was immediately resumed. In spite of the heat-generating properties of this violent shivering, the body temperature also decreased steadily, though not keeping pace with the more rapidly de-

creasing ambient temperature. The heat generated by this rapid muscular activity apparently accounted for the evident partial resistance to the lowering of external temperature. As the refrigerator came to equilibrium at about 5.7°C., the bat's temperature remained nearly constant, 18.0°C. To avoid killing the animal from prolonged exposure to the low temperature (this occurred in a previous run of the experiment), the refrigerator was turned off and the heater turned on inside the chamber. The ambient temperature rose in one minute to 13.7°C., while in the same length of time the bat's internal temperature rose to 20.6°C. The shivering did not cease, but steadily continued. The rise in body temperature followed approximately the same slope as the rise of external temperature. As the body temperature approached 31.5°C. another short attempt at struggling was made. At 32.6°C. the shivering stopped and, as the ambient temperature continued to rise, the animal initiated a series of wing-flappings. At each flap the wings were relaxed and allowed to fall to a half-open position. The wings were then drawn quickly up in a short arc so that they were tightly held to the body. This complete movement was executed about twice per second. This motion of the wings requires little muscular effort and it is very effective in passing air over the naked membrane, and is of undoubted value as a mechanism for heat exchange. So long as the temperature gradient is favorable the increased flow of air over the vascular membrane would clearly increase the heat losses from the wing.

For five minutes this flapping was adequate to maintain the body temperature at a constant 32.6°C. This fact may indicate that this temperature is the optimum internal temperature. The ambient temperature during this time had reached and eventually exceeded the internal temperature. The rate of flapping had gradually risen to about three beats per second. In spite of the increased ambient temperature to above that of the body, and the consequent reversal of heat flow, the higher rate of wing flapping continued and the body temperature rose in response to increased external temperatures. The flapping increased in rate until, at 34.7°C. internal temperature, the animal began alternating the flapping with a fanning of the completely spread wings. This beating of completely open membranes would last from five to ten seconds, then the rapid flapping would resume for approximately thirty seconds. At 38.2°C. a convulsive wrenching action of the body was made in an attempt to free the bonds. At 38.7°C. the bat began a constant fanning of the outstretched wings, which lasted the next 26 minutes of the experiment, at the end of which time the fanning had slowed appreciably and the animal showed signs of extreme fatigue. The environmental temperature leveled off at about 40.6°C., at which time the internal temperature became nearly constant at 39.0°C. The constant fanning of the wings was apparently adequate to maintain this lowered temperature, a condition suggesting the possibility of some heat loss by evaporative cooling or radiation of heat to the refrigerator walls. In order to prevent the death of the experimental animal, it was removed at this time from the chamber. The animal was weak, but showed a strong inclination to fly, until apparently cooled by the room temperature, at which time it relaxed.

These experiments seem to indicate that *Macrotus* is better able to regulate its internal temperature than is *Myotis*. This would at least be a factor in the obligation to migrate which is apparent in certain species of bats. Stager (1939) has found that *Myotis velifer* was present in the Riverside Mountains from April 7 to August 28. During the midsummer period this species is found in great numbers, while there are very few in spring and in fall. The animals are found during winter in the regions of southern and central Mexico, apparently having migrated from the northern and, in winter, less temperate regions. *Macrotus californicus*, however, is found at any time during the year in the Riverside Mountains. The temperatures of resting *Macrotus* in winter at the roost have never been reported. It appears from our experiments, however, that this form is prone to regulate and maintain an internal temperature higher than that of the environment though the ambient temperature may be very low. *Myotis velifer*, however, has shown little regulation at the lower ambient temperatures. It being a tropical form, the lack of ability to regulate efficiently is not surprising, though rather efficient thermoregulation has been reported in the case of *Pteropus* (Burbank and Young, 1934).

One of the most interesting results of the experiment is found in the fact that even when the environmental temperature was considerably above that of the animal the bat still continued its rapid wing motions. Normally, this beating in the heated air would serve to generate internal heat and would also promote heating the wing and blood passing through it. Nevertheless, as may be seen from Figure 2, the body temperature was rather effectively maintained at a sub-environmental level, clearly indicating the existence of an effective heat dissipating mechanism. Although this circumstance may indicate the presence of evaporative cooling from perspiration on the wings and uropatagium, radiation losses are equally probable. No sweat glands have been discovered in histologic investigations of the wing tissues, and, therefore, it seems probable that heat loss must take place by means of respiratory evaporation or movement of imperceptible water vapor from flight membranes, or by radiation to the surrounding walls of the refrigerator.

In the Lump-nosed bat, *Corynorhinus rafinesquei pallidus*, it has been shown that to be capable of flight the rectal temperature must be at least 24.3°C. This was determined by repeatedly pushing a torpid bat from a four-foot height. The animal would fall onto a pad on the floor until a body temperature adequate for flight was attained by the bat. Immediately upon the first sign of flight, the animal was captured and its rectal temperature ascertained.

In *Myotis yumanensis* about 15 minutes were required to raise the temperature from 11.5°C. to 31°C. This temperature rise was due in part to assimilation of ambient heat, and in part to the shivering mechanism previously mentioned. When tossed ten feet into the air, an animal with body temperature of 30 degrees centigrade fluttered down to the floor. At 31 degrees, it was barely able to fly with awkward, jerky movements. At 33 degrees rectal temperature, the bat was capable of dodging and avoiding obstacles in the room while flying, and was also able to launch flight by jumping vertically from a flat surface.

When kept in constant flight for four minutes, *Myotis yumanensis* raised its temperature from 33° to 40°C., thus elevating its internal temperature about 1.7 degrees per minute of flight. By keeping the bat from landing on surfaces in the room, in another trial, it was kept in flight for 30 minutes. At this time the body temperature was 40.8°C. Thus, in flight, heat is dissipated from the body at about the same rate as it is produced in the flight process. Since this heat was sufficient to elevate the body temperature 7 degrees in the first 4 minutes of flight, it is evident that the amount of heat that must be dissipated from the body during normal flight is considerable.

The mechanism of rapid heat dispersal in bats has been reported by Cowles (1947). The ratio of naked vascularized areas of wings and uropatagium to insulated fur-covered body has been determined by use of a planimeter, and is impressive. In the Nearctic bats measured, this ratio varied from approximately 4 to 1, in *Eptesicus fuscus*, to 8.5 to 1, in *Antrozous pacificus*. As nearly as could be obtained from tracings, the tropical fruit bat, *Pteropus*, demonstrates a ratio of 11 to 1 of vascularized and naked to fur-covered, insulated areas. The naked regions of the body of the bat are comprised of the wings, uropatagium, and the ear surfaces. All of these parts are heavily vascularized with large arteries and veins, and especially with very fine ramifying and anastomosing capillaries. The membranes are thin, except for parts of the ear, and the vascular tubules are very near to the surface, most being exposed to both surfaces of the membrane.

Nicoll and Webb (1946) have investigated the process of circulation within the bat wing, especially as it might aid in the understanding of human capillary circulation. They have shown that there is an extensive system of precapillary sphincters within the naked membranes which, through vasomotion of these muscles and the arteriole walls, rhythmically, but not simultaneously, flush the capillary plexi with blood. They have concluded that this is a mechanism which allows a minimum volume of blood to serve the metabolic needs of the tissue. Only a fraction of the total volume of blood which would be necessary to entirely fill the capillary beds in the membranes is involved in fulfilling the metabolic needs of these regions of the body.

In *Myotis*, at internal temperatures up to about 39°C., the smaller blood vessels, while readily perceptible, appear collapsed, and the blood content is low. This condition is illustrated in Plates I, upper, and II, upper, which show the normal appearance of the wing vessels while the animal is in a resting state. When the bat is further heated until the internal temperature is 41 degrees, approximately, or higher, there is a sudden flow of blood from the larger vessels leading into the wings, into the capillary plexi of the naked membranes. This engorgement is rapid and completely fills the entire vascular system of the wings, uropatagium and ears. The precapillary sphincters have apparently relaxed, and it is apparent that blood normally circulating in other parts of the body, most probably the viscera, has been shunted into the peripheral vascular system. Looking at the smaller vessels through a dissecting scope, it is seen that these vessels are dilated and expanded by the pressure of the circulating blood, (Pls. I, lower, and II, lower).

This process is not an all or nothing response, as there is a slight increase in

blood in the naked membranes at about 39 degrees, though this point differs to some extent in various trials. However, the final emergency engorgement comprises the simultaneous vasodilation of the smaller vessels, and relaxation

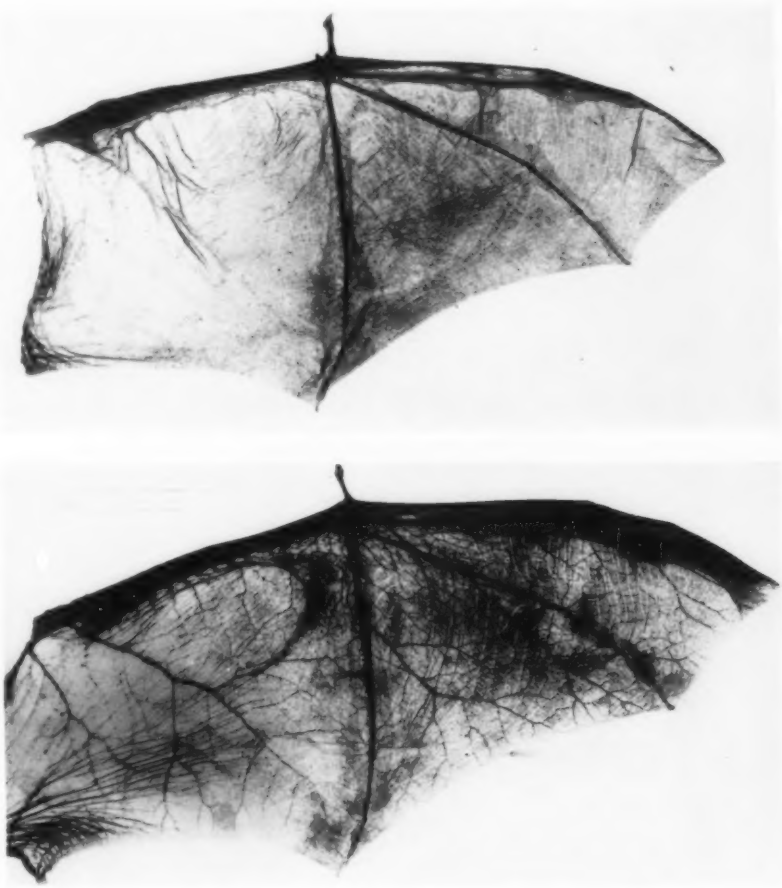

PLATE I

UPPER: Wing of *Myotis yumanensis* showing extent of blood perfusion as seen at rectal temperatures up to about 39° C.

LOWER: Wing of *Myotis yumanensis* showing engorged state of vascular system as observed at a rectal temperature of about 41° C.

of the pre-capillary sphincters, thus allowing maximum volume of blood to be rapidly and extensively circulated in the very thin membrane.

Especially during flight, the cooling air very rapidly is passed over the surfaces

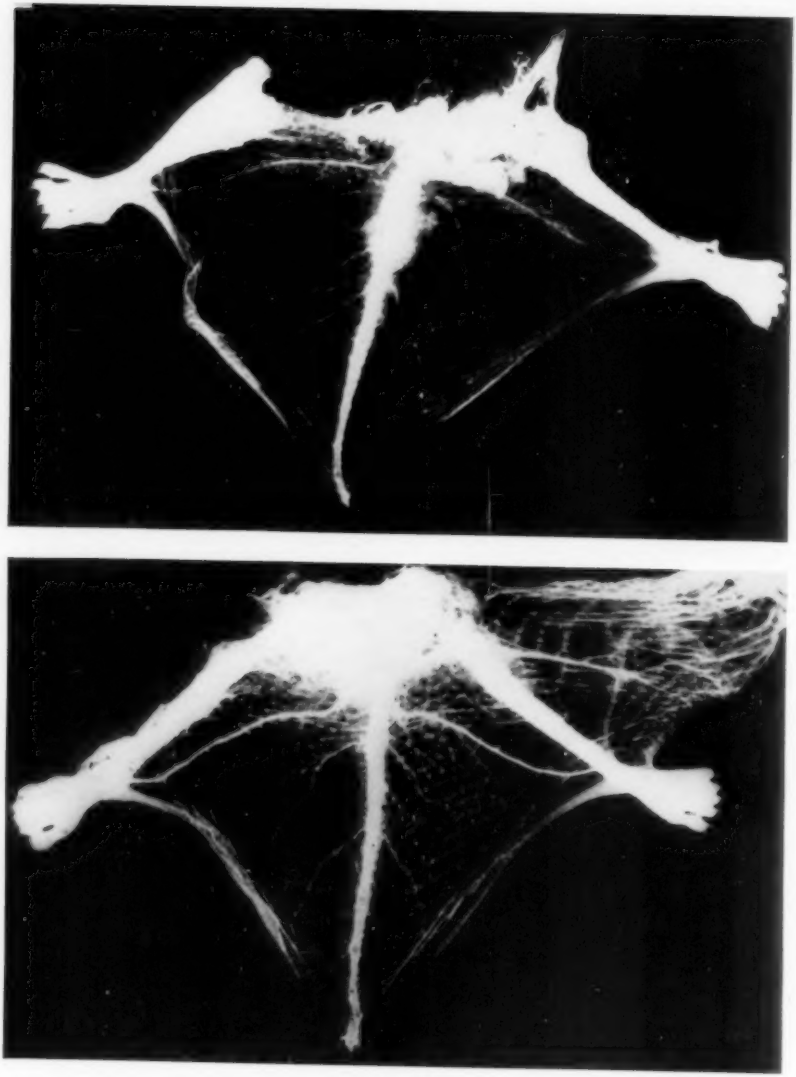

PLATE II

UPPER: Uropatagium of *Myotis yumanensis* showing extent of blood perfusion as seen at rectal temperatures up to about 39° C.

LOWER: Uropatagium of *Myotis yumanensis* showing engorged state of vascular system as observed at a rectal temperature of about 41° C.

of wings, uropatagium, and ears. Without doubt, heat dissipation from the wings is very rapid during the period of emergency engorgement. A. D. Moore (in litt.) expressed the view that a thermal difference of 1°C. should serve to dissipate all heat of metabolism. This engorged condition has been observed under strictly artificial, and also under more natural, conditions in the laboratory. By means of infra-red heat lamps, the temperature of the air was raised to a point where bats confined in a wire cage attained body temperatures of over 40°C. As the temperature of the animals approached 33 degrees, rapid movements of half-opened wings were initiated. At 34°C. the series of fanning movements with the outstretched wings of about five seconds duration were alternated with the beating of the half-opened wings for about 30 seconds. At 38°C., the constant fanning of the fully-opened wings was initiated. As the temperature of the environment continued to rise, so did that of the body, though not in direct proportion. The fanning showed slight cooling efficacy, because the internal temperature increased to 42.5°C. when the complete engorgement occurred. At this point the body temperature leveled off. Fanning of the wings was continued for several minutes, at which time the animals showed signs of extreme fatigue as indicated by a slowing of the wing beat and decrease in the strength of fanning movements. The animals were, therefore, taken from the system. When the animals were heated in a confining area, in which no wing movements could take place, but in which air circulation was similar to the larger cages, the individuals died when their body temperatures were increased above 42°C. The exact point of expiration was difficult of determination, due to the animals' primary collapse.

To determine the extent to which this heating occurs under natural conditions, individuals of *Myotis yumanensis* were made to fly continuously for periods up to 30 minutes, with a room temperature of 28.5°C. One individual flew for 30 seconds; the body temperature was 39.0°C. and no engorgement was in evidence. A second bat flew for five minutes; the body temperature was 40.0°C. with no vasodilation. A third animal flew for four minutes, body temperature was 40.3 degrees centigrade with no vasodilation. The fourth animal flew for 30 minutes, being kept from landing during this time by the operators. The body temperature was 40.2°C. Vasodilation and complete engorgement were apparent upon his capture. Thus it would seem that the mechanism of circulation of blood through the heavily vascularized membranes was resorted to only during emergencies, as in especially prolonged flight. How long the engorgement continued in the latter case before it was observed at the end of the experimental period is unknown.

The return of the animals from the engorged condition to the natural state involves gradual elimination of the blood from the vascular membranes. This takes place over periods up to 15 minutes in length. Very possibly, this is carried out by the process of vasomotion, which has been described extensively by Nicoll and Webb (1946). In all cases except where heated in a confining space, the animals remained alive after experimentation and appeared no worse for their experience.

The method of photographing the wings of bats, employed by R. B. Cowles, consists of using the wing itself as a "projection negative" and, with the aid of an enlarger, producing what is in reality a negative print. From this a photograph was obtained and used for a second projection. The greater the amount of blood in the vessels the greater will be the density, and, thus, the engorged vessels stand out as light lines against the background of the membrane, which is more photopermeable.

This thermoregulation at high temperatures is not only important in regulation of somatic temperature, but also maintains the body below the theoretical maximum that might involve the thermal tolerance of the male germinal tissues. Because of the relatively high body temperatures of the Microchiroptera, and the remarkable heat generation during flight, it is of interest that these animals are exceptional in another manner, namely, in most species of Nearctic bats, spermatogenesis is carried on during the hottest months of the year (July, August, and September) followed by testicular inactivity during the period of winter hibernation. In this respect these animals differ markedly from the usual spring breeding encountered in most temperate zone vertebrates. This hot weather mating of the bats may be associated with their tropical origin and thus it may function as an adaptation that makes possible their invasion and occupation of the temperate zone. However, before it can be concluded that this hot weather breeding places the bats in the category of exceptions to the rule of thermal spermatogenic sensitivity, it should be remembered that they are nocturnal, that nights are lengthening and daytime hours diminishing from June 21 onward, and that their temperatures are more dependent on a combination of activity and external conditions than is true of many animals. Of even greater importance is the location of the testes during this spermatogenic period. In breeding bats, the testes descend into the uropatagium where cooling should be fully as adequate, if not more so, than in a more conventional scrotal arrangement.

DISCUSSION

In line with the expectation that at environmental temperatures above the optimum for the body there would be a diminution in the membranous blood supply, the bats were subjected to external heat loads which raised body temperatures to 42.5°C. This is apparently the lethal for *Myotis yumanensis*.

Contrary to expectations, there was no diminution of the blood supply at this high external temperature, and a re-examination of the problem suggests the logical probability that bats could achieve little or no relief from overheating resulting from externally high temperatures. This condition may be due to the necessity of maintaining at least a minimal supply of blood in the tissues of the membranes. In line with all cellular physiology, metabolic activity presumably would be increased by high temperatures and a reduction of the flow of blood might jeopardize the health of the membranes. If this is the case, then bats must avoid environmental temperatures above their optimum, since, without evaporative cooling, heat would be absorbed and transmitted to the body. If this is a correct interpretation of their problems, daytime roosts in caves or forests are

essential to survival, and nocturnal flight when the spread wings would not be exposed to heat must be obligatory. The exposed roosting places of some of the flying foxes seem contradictory and may subject them to the danger of overheating, but it has been noted that they engage in considerable fanning activity, and there has been no analysis of environmental condition, nor record of internal temperatures.

One of the unexpected observations resulting from these studies has been the marked aversion of these bats to exposure to moderate heat from an infra-red source. The animals are apparently extremely sensitive to heat intensities that are barely uncomfortable to the human hand, and it was noticed that they preferred to move toward the intense light of a 60-watt bulb placed twelve inches away rather than seek darkness in the direction of the heat lamp. The exact locations of the heat sensitive areas were not discerned, but in the preliminary tests it was noticed that the face and ears seemed particularly sensitive although the wings also react and are withdrawn from even moderate temperatures in a manner suggesting delicate heat perception. In the red bat (*Lasiurus borealis teliotis*) a humanly gratifying temperature (31°C. on an unblackened thermometer, and 59°C. on one with a blackened bulb) caused the wing to be withdrawn sharply. Both heat and cold result in a precipitate folding of the wings, and in the closed position the membranes are thrown into innumerable very small plicae that result in the formation of multitudinous air pockets. This arrangement should retard both heat loss and absorption.

The shivering mechanism, possibly in conjunction with other heat producing processes, is utilized to raise the body temperature of the torpid bat to the minimum level necessary for coordinated muscular activity. Therefore, the daily fluctuation in the animal's temperature, found even in the parts of the year during which the animal is active, may be influenced to a great degree by the animal itself, by initiation of heat-producing or heat-dissipating activities. However, there seems to be an environmental temperature maximum and minimum beyond which the animal is unable to maintain its temperature within the range of thermal tolerance without initiating flight or a rapid fanning, presumably for the purpose of evaporating moisture from the membrane surfaces or, if the environment is colder than the animal, losing heat by radiation.

Apparently the large Megachiroptera, the tropical fruit bats or flying foxes, have relatively stable temperatures. Burbank and Young (*ibid.*) point to the notable difference in temperature regulation that exists between these animals and the Microchiroptera, namely, that in the fruit bats shivering starts when body temperatures fall, and thus chilling is prevented, whereas in the Microchiroptera shivering is employed only on waking and is thereafter used to generate the desired temperature.

SUMMARY

In vertebrates capable of true flight, a great excess of heat is produced during periods of locomotion. In bats of the suborder Microchiroptera, the vascular system of the wings is modified by a series of precapillary spincters which

enables a minimum amount of blood to nourish the membrane. At a rectal temperature of about 40°, emergency thermoregulation is apparently necessary, for the entire vascular network of the wings and uropatagium is flushed with blood which has been shunted from other parts of the body. This mechanism, as a radiator, allows for a great amount of heat to be conducted from the membrane to the surrounding air in a short period of time.

Except during periods of activity, these bats are essentially poikilothermic. A temperature control chamber was used to simulate changes in ambient temperature typical of the natural environment. It was found that when the environmental temperature was lowered to 5° centigrade, the rectal temperature of a specimen of *Myotis*, with slight thermal lag, fell to 5.8°C. *Macrotus*, however, reacted differently to a lowered ambient temperature, as it appears to regulate the internal temperature with some efficiency. When the temperature of the enviornment dropped to 5.7°C., the rectal temperature of the bat remained at a level of 18.0°C. These data correlate with the habits of the respective animals; *Myotis velifer* migrates southward during the cooler parts of the year while *Macrotus californicus* may be found in its typical localities throughout the entire year.

In activating themselves from the cold lethargy, the bats may employ the expedient of shivering, which apparently is effective in raising the body temperature to a level sufficient for flight; in *Myotis yumanensis* the minimum thermal level for flight is about 31°C.

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EASTERN PACIFIC RECORDS AND GENERAL DISTRIBUTION OF THE PYGMY SPERM WHALE

BY CARL L. HUBBS

Though now regarded by cetologists as a cosmopolitan species less rare than it was previously thought to be, the pygmy sperm whale, *Kogia breviceps* (Blainville), has been reported only three or four times from the vast length of the eastern Pacific shoreline. Until very recently, in fact, the only New-World Pacific record was that of "Lower California," from which assigned type-locality Gill (1871, p. 736) described the nominal species, *Kogia floweri*, with the hope, long unfilfilled, "that this article may incite our California friends to seek for and procure specimens." This indefinite and inclusive locality was presumably incorrect, for Lyon and Osgood (1909, p. 4) stated that the type material (No. 8016, United States National Museum), comprising a mandible and a water-color sketch, was from "off Mazatlan, Sinaloa, Mexico." Hirasaka (1937, p. 120), presumably on advice from Glover M. Allen, listed the locality as "off Mazatlan, Lower California" and Allen himself (1941, pp. 19 and 23) gave it both as "near Mazatlan, Mexico" and as "Lower California." Trusting the museum record, we assume that the specimen was taken in the vicinity of Mazatlán, Sinaloa, México, near the mouth of the Gulf of California, in warm water with a definitely tropical fauna.

The second eastern Pacific record was added by Hirasaka (1937, p. 122), on word from Glover M. Allen, as "Independentia, Peru." Allen (1941, p. 19) repeated the record, as "beach at Independencia Bay, Peru," adding that the specimen was "interesting as occurring in the region of the cool Humboldt Current, though it may, of course, have washed in from a warmer area of the adjacent seas." Its provenance from warm water seems highly improbable and, in view of the next record, quite unnecessary to assume.

A third record from the eastern Pacific (the second from the northeastern Pacific) has just been given by Scheffer and Slipp (1948, pp. 307–309, figs. 41–42) on the basis of a young male specimen that was washed ashore on the cold outer coast of Washington. They add an additional plausible though hearsay record from near Cape Flattery, Washington.

First California record.—The first California record is based on one of the photographs (Pl. I), now deposited in the Scripps Institution of Oceanography, that were collected by the well-known marine game-fish sportsman and author,

Charles Frederick Holder. On its reverse side the print carries the notation "Sept. 6, 1936/opp. end of 25th St. on Beach/Balboa, Calif." Since Holder was a competent naturalist, there can be very little doubt as to the authenticity of the data.

It is obvious that this photograph represents an adult pygmy sperm whale. It corresponds very well with the photographs published by Scheffer and Slipp and almost surely represents the same species, whether or not more than one kind of *Kogia* be recognized. Agreement is good in the dark color; in the short flippers; in the laterally turgid head, with the eyes at the summits of bulbous swellings (presumably exaggerated by the shrinkage of the snout); in the very strongly projecting and bluntly pointed snout; and in the short, inferior, anteriorly rounded mouth, with the sides of the gape rather strongly divergent

PLATE I

Specimen of pygmy sperm whale stranded at Balboa, on September 6, 1936. From photograph in collection of Charles Frederick Holder

posteriorly. It certainly does not represent a young sperm whale, *Physeter catodon* Linnaeus, for the head and the jaws are of quite different shape. It resembles no recognized species other than *Kogia breviceps*. Dr. Remington Kellogg has concurred in this identification.

Second California specimen.—The second specimen came ashore during a violent onshore storm, presumably on the night of December 9, 1949. Still alive, it was discovered by Ray Riggin of Imperial Beach about 8:00 A.M. on December 10, on the sand beach opposite Tijuana Slough about one-fourth mile north of its outlet, between San Diego Bay and the Mexican border. Mr. Riggin promptly notified Scripps Institution of the find. Following our advice he, with the help of neighbors, tethered the odd beast by a hauser to a steel stake, to prevent it being washed to sea by the incoming tide. The *Kogia* was still breathing when I arrived on the scene about 10:30 A.M., with volunteer assistants from the Institution. After washing down the somewhat desiccated skin with water from the surf, we rolled the little whale onto a tarpaulin and dragged it across the sandspit

into the lagoon. We then pulled it by the heavy rope, tail first, toward the end of the road about one-half mile north. Gradually, in its natural medium, the animal recovered enough strength to give several of us quite a struggle. About noon we pulled it over a timber ramp onto a stake truck, covered it with wet blankets and then hastily drove to Scripps Institution. On arrival about an hour later the whale gave proof of having survived the trip by breathing heavily, but

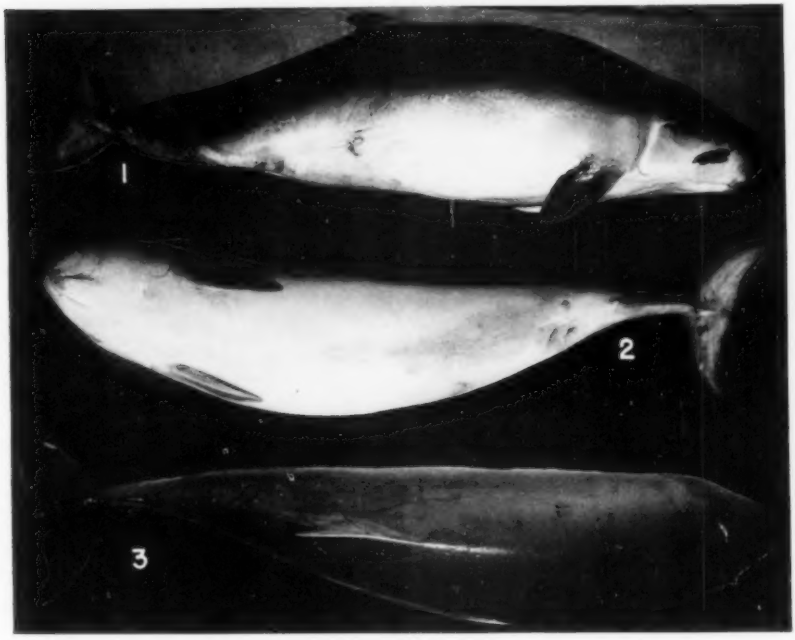

PLATE II

Lateral, ventral, and dorsal views, respectively, of a pygmy sperm whale collected near Imperial Beach, December 10, 1949. Photographs by John B. MacFall, Scripps Institution of Oceanography, December 11, 1949

it failed to recover despite efforts at artificial respiration, after being promptly immersed in an adequately large concrete tank.

During the following day the choice specimen, still in excellent condition, was photographed from various angles (Pls. II–III), measured thoroughly (Table 1), cast by Leon J. Pray for a lifelike display now on exhibit at the San Diego Museum of Natural History, and completely skeletonized for the growing cetacean collection of the San Diego Society of Natural History. Samples of the blubber were utilized in underwater sound research at Scripps Institution. Neither time nor energy was left for any extensive dissection or description of

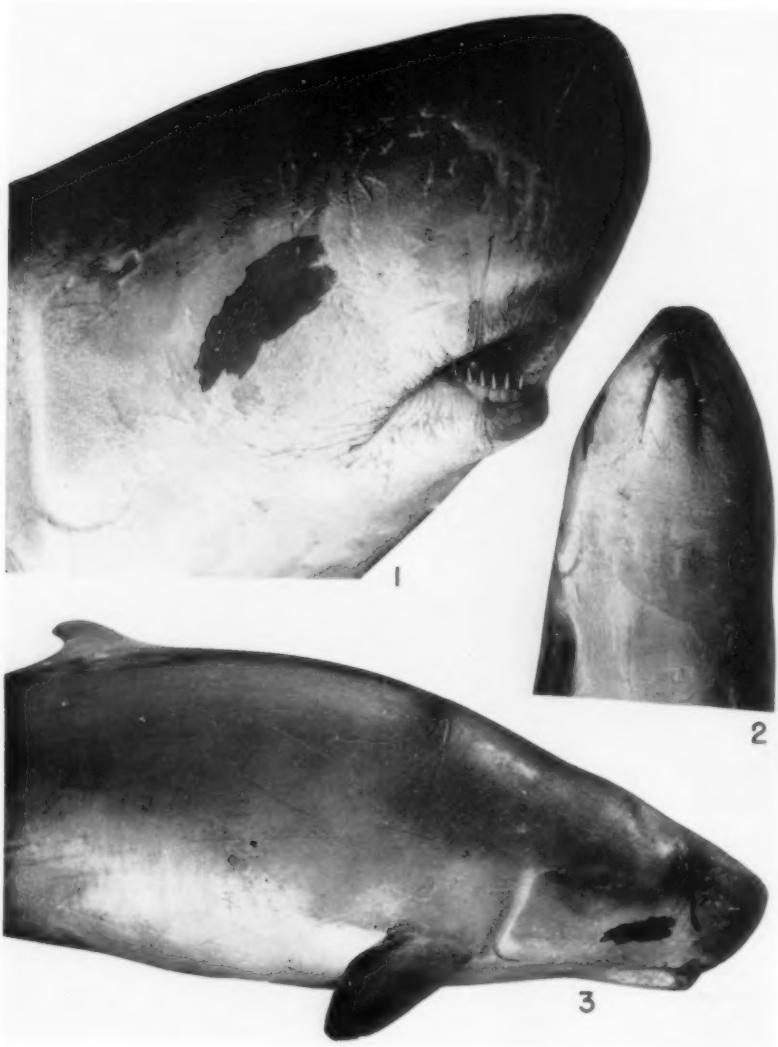

PLATE III

Pygmy sperm whale collected near Imperial Beach, California
(1) Oblique view of mouth, showing teeth
(2) Ventral view of head, showing form, mouth, and coloration
(3) Detail of anterior lateral parts, showing texture, coloration, and parasitic copepod

TABLE 1.—*External measurements of pygmy sperm whale from near Imperial Beach, California*

All measurements, except circumference, were made in a straight line between specified points

Total length (mm.) from tip of snout to: Farthest tip of flukes	2490
Line joining tips of flukes	2465
Notch at middle of flukes	2345
Proportions in thousandths of length to notch in flukes	
Greatest half-circumference (on one side of body)	330
Distance from tip of snout to line of greatest circumference	394
Depth of body: From origin of dorsal fin to end of genital slit	246
Over front of anal slit	178
At origin of flukes	70
Width of body: Greatest width	190
Least width	26
Opposite front of mouth	74
From eye to eye	157
Opposite middle of anus	88
Least distance between flippers	96
From tip of snout to: Front of mouth	82
Front of blowhole	116
Front of eye	156
Insertion of flipper	246
Tip of flipper	379
Front of dorsal fin	499
Tip of dorsal lobe	638
Front of genital slit	429
Front of anal slit	685
Length of external genital slit	75
From rear of genital slit to front of anal slit	217
Length of anal slit	43
From rear of anal slit to notch in flukes	281
Gape from inside of upper lip: To internal end of gape	44
To extreme end of crease	70
Between ends of crease of gape	37
From end of gape to insertion of flipper	128
Blowhole width	30
Orbit length	9
From orbit to: Blowhole	94
Corner of gape	83
Insertion of flipper	105
Flipper: Insertion to tip	134
Basal width	66
Greatest width, near middle	54
Dorsal fin: Origin to tip	147
Vertical height	66
Flukes: Greatest overall width	242
From notch to tip	132
From origin to notch	87

the internal anatomy. The external characteristics, however, were noted in some detail.

Description of the Imperial Beach specimen.—In top view (Pl. II, 3) this un-

bloated specimen was slick and streamlined, with a rather sharply pointed snout and a very slender caudal peduncle. The area of greatest cross-section was located at 37 per cent of the distance from the entering wedge to the end of the tail race—approximately at the location (36 per cent) to be expected in a perfectly streamlined body. In side view (Pl. II, 1 and Pl. III, 3) the head was subrectangular, with a steep curve from the preposterously small mouth to the very broadly rounded snout. The dorsal contour was slightly convex in a region just above and behind the eyes and was gently curved between the nape and the dorsal fin. As seen from below (Pl. III, 2), the head was very broad behind the subconical snout, with only a slight bulge in the general region of the eyes. The high dorsal keel of the caudal peduncle was weakly continued forward into the postdorsal keel (Pl. II, 3). The form of the fins is shown in the figures.

The upper parts were dark gray with a somewhat bluish tinge, becoming almost black dorsally. The head was dark downward well toward the mouth and in a circle around the eye. About halfway between the eye and the tip of the snout the light color extended upward to well above the middle of the height of the head. The tip of the chin and the adjacent parts of the snout were dark (Pl. III). There was a large jet-black blotch on the right side, between eye and mouth. The dark color of the back, diluted to gray, extended downward to the blackish-topped flippers and to the same level for some distance backward (Pls. II and III). Behind this area, the whitish to light-gray ventral color extended across the lower half of the trunk. Behind the anus the dark color dropped downward to cover the ventral keel and, with some dilution, the lower surface of the flukes. The flippers became abruptly white on the inner surface (Pl. II).

A pair of very striking bracket-like marks, which I have not seen figured or described, were symmetrically disposed on the two sides of the head between the eye and the flippers (Pl. II, 1; Pl. III). Most of the mark, including all of the upper part, was whitish, but the lower parts were bounded behind by a blackish streak that became narrower and darker around the lower hook. This mark looked strangely like the gill opening of a teleost fish, but I see no significance in this resemblance.

At the forward-hooked upper end of this mark, not far behind the eye, there was the small external opening of the ear (Pl. III). Charles L. Camp informs me that he found the ear opening at this end of the color mark in an adult female, that was stranded years ago near New York, and in its embryo, and, further, that he located, in both the female and the embryo, near the lower end of the mark, an opening that led into a large, presumably glandular, cavity. It seems probable that the mark is characteristic of the genus.

The few slightly incurved needle-like teeth diverged rather strongly on the sides of the mandible (Pl. III, 1).

No pathological conditions were noted to which the stranding or death of the creature could be ascribed. A very large copepod of the genus *Pennella* (Pl. III, 3) was attached dorsolaterally, about equidistant from eye and snout tip. On the right flank in advance of the anus there was a large curved scar, well healed (Pl. II, 1). There were other healed scars, possibly produced by other males in combat, on the side of the snout (Pl. III). The stomach was empty.

Sex and maturity.—Despite its small size, less than 8 feet overall, the Imperial Beach specimen was an apparently mature or nearly mature male. The scars just mentioned suggest maturity. The skull bones seemed to be thoroughly ankylosed. Each testis was about 1 x 4 inches in size and the penis was about 18 inches long.

It may be a coincidence, of course, that the specimen reported from Washington by Scheffer and Slipp was also a male, but it may well be that only males wander far to the north. That is the habit of the sperm whale, *Physeter catodon* Linnaeus. Confirming published accounts, officials of the two whaling stations that have been operating recently off western North America (at Fields Landing, northern California, and at Coal Harbour, British Columbia) have reported that they have very seldom taken a female sperm whale.

Distributional considerations.—Geographically and ecologically, these record stations in southern California nicely bridge the broad gap between the previously reported regions of occurrence on the Pacific Coast of North America, namely in the Gulf of California and in Washington.

No critical consideration is here given to the current view that all kogiids are referable to a single species. The accepted idea of the cosmopolitan distribution of a single species finds support in the broad distribution of pygmy sperm whales through tropical and temperature seas, as determined and mapped by Hirasaka (1937, pp. 119–122, map 1) and as confirmed by the more recent reports, including Edmondson's (1948) records from the Hawaiian Islands.

The new eastern Pacific records, however, do not confirm Hirasaka's opinion that in temperate regions *Kogia* is confined to warm currents of tropical origin and that the young are found only in the more tropical parts of the range. The three or four recent Pacific records all lie in regions of cool currents and much upwelling, far from flows of tropical origin. Similarly, the east coast of the South Island of New Zealand and the southwestern tip of Africa, from each of which there are several records, are not subtropical. The relatively numerous records from the east coast of North America, from Florida to Nova Scotia (Allen, 1937, pp. 19–24), do suggest an especial abundance in waters tempered by the Gulf Stream, but the few reports from Japan (Hirasaka, 1937) hardly justify the generalization that the pygmy sperm whales are commonest in warm currents of tropical origin. Nor does the small size (1885 mm. to notch in flukes) of the specimen from near Grayland, Washington, confirm Hirasaka's opinion that the young occur only in the more tropical parts of the range of the species. We may conclude that *Kogia* is widely distributed around the world in temperate as well as tropical waters.

Kogia breviceps is the third recent addition to the known whale fauna of the western United States. The other two are the beaked whales, *Mesoplodon bowdoini* Andrews and *Ziphius cavirostris* Cuvier (Hubbs, 1946, and subsequent reports for *Ziphius*).

Gastronomic considerations.—Having enjoyed eating the flesh of the *Mesoplodon* reported in 1946 (it was particularly welcome during the war-time period of red-meat shortage), the staff of Scripps Institution and friends ate a large part of the deep-red flesh of the pygmy sperm whale. Reports ranged from disgust to en-

thusiasm. I thought this flesh to be somewhat stronger in flavor and less delectable than that of the beaked whale. No ill effects were experienced by any who partook of the meat of either species. In this connection we may recall published statements to the effect that the flesh of beaked whales is considered poisonous in Norway (a supposition that may well be unfounded) and that sperm whales (*Physeter*) are rated low as human food.

Acknowledgments.—I am happy to express appreciation to Ray Riggin of Imperial Beach, who found the pygmy sperm whale just discussed, secured it, and aided in its transport, and to various colleagues and students at Scripps Institution, including Sam D. Hinton, W. E. Barraclough, Al. A. Allanson, Frederick H. C. Taylor, and, as usual, my good wife, Laura. Remington Kellogg, Victor B. Scheffer, and Charles L. Camp generously furnished data.

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AN ANALYSIS OF THE REPRODUCTIVE PATTERN OF WHITETAIL DEER IN SOUTH TEXAS

By Denis Illige

Because a species may vary considerably in its breeding habits at different latitudes, a study was undertaken to gather specific data on the reproductive behavior of the whitetail deer, *Odocoileus virginianus texanus* (Mearns), in southern Texas. The three objectives of the study were: (1) to determine more accurately the period and duration of the breeding season; (2) to provide data on breeding success; and (3) to ascertain some of the physiological and anatomical changes in the male and female correlated with the annual cycle of reproduction.

The population samples providing the data were from Kenedy and Kleberg counties, Texas, collected primarily by Richard B. Davis for a study of the food habits and numbers of deer on the live oak–mesquite ranges of South Texas.

Materials and field data for the investigation were collected by Dr. William B. Davis, Richard B. Davis, and me from September, 1948, to March, 1950. Techniques and data resulting from whitetail deer investigations in New York by Cheatum (1949), Cheatum and Morton (1942, 1946), Cheatum and Severinghaus (1950), and Severinghaus (1949) provided a ground work for this study. Dr. R. O. Berry, Department of Animal Husbandry, Texas A. and M. College, offered valuable assistance and advice during the course of the study.

General methods and procedures.—Richard Davis collected ten deer each month, five on each of two study ares. Later he collected five specimens per month from only one area. At first, an attempt was made to provide two age classes for each sex and an additional fawn of either sex. Techniques, particularly as developed by Severinghaus (1949), later demonstrated that it was not possible to separate all yearlings from adults in the field, on the basis of size and general appearance. We removed the reproductive tracts of both males and females in the field, but took no field measurements of them prior to February, 1949, when I assumed responsibility for the study. I was in the field with Richard B. Davis about three days each month to assist with collecting, to take measurements, to make personal field observations, and to co-operate with the food-habits study. We recorded the standard measurements of total length, length of tail, and length of hind foot of each deer, as well as measurements of chest girth and weight to the nearest half-pound, first entire and then eviscerated. Later in the study, the lower jaws were removed and saved for laboratory checks on the age of specimens.

At first the complete reproductive tracts were preserved in 10 per cent formalin. Later, in an attempt to improve preservation for histological study, I used Bouin's solution for a small piece of testicular material and the ovaries, and fixed another small piece of teased testis in acetic alcohol to have material available for determination of chromosome number. Comparison of earlier collected material preserved in formalin with that fixed in Bouin's indicated

that the special preservation did not result in preparations sufficiently improved to warrant the use of the extra time and effort.

Laboratory analysis of male reproductive tracts.—In the laboratory the remaining whole testis was separated from the tract, the epididymis removed, and its volume determined by positive displacement of water. The apparatus used for volumetric studies was a modification of a standard manometer designed for determination of gas volumes. It was simple in construction and operation, consisting of a 50 ml. burette graduated in tenths of a cubic centimeter, a length of rubber tubing, a vessel large enough to hold the testis, clamps to hold the burette and the receiving vessel, and a straight edge for a reference line.

The apparatus was filled with water to a reference line placed about midpoint on the receiving vessel, the level of the liquid was recorded and then a testis was placed in the receiving vessel. By lowering the burette until the meniscus

TABLE 1.—*Ratios of volume of testes to diameter of seminiferous tubules and condition of antlers in whitetail deer*

MONTH	ANTLER CONDITION	NUMBER TESTES MEASURED	AVERAGE DIAMETER OF TUBULE IN MICRONS	AVERAGE VOLUME OF TESTIS IN CC.	RATIO
June	Antlers beginning to fork	2	136.5	8.4	.061
July	In velvet, forked	4	113.2	9.7	.085
August	In velvet, forked	2	152.3	14.2	.093
September	Shedding of velvet begins	6	172.3	27.0	.156
October	Shedding of velvet continues	4	181.2	30.1	.166
November	All velvet shed	6	181.0	32.7	.180
December	All velvet shed	2	145.0	34.2	.235
January	All velvet shed	4	141.3	29.3	.207
February	Shedding has begun	1	129.2	17.2	.133
March	Most have shed	4	126.8	8.5	.067
April	New growth appears	2	122.5	7.3	.059
May	All have at least nubs in velvet	2	122.5	8.0	.065

in the receiving vessel returned to the reference line, we derived a second reading and recorded the difference between the two as the volume of the testis in cubic centimeters. A check of the apparatus by using known quantities of water introduced by a pipette graduated to .01 milliliter revealed the method to be accurate within one per cent.

Testicular volumes were recorded for specimens collected in each month and the average size tabulated (Table 1). The average volume increased appreciably from August to December and decreased from January to March, with the minimum size occurring in April and May. To reduce the possibility of introducing the factor of animal size into size measurements of testes, the ratio of volume of testis to total length of animal was calculated. Estimating an error of plus or minus three inches in measuring the total length of specimens in the field, the calculated percentage of error between the largest and smallest animal was approximately 7.5. The monthly ratios are shown in graph form (Fig. 1).

If the volume of a testis is a reliable indication of sexual activity, the ratios

should depict a true index to the ascent, peak, and wane of male reproductive capacity in whitetail deer regardless of size of animal. This ratio is at a stable level in April, May, and June. In July and August there are slight increases each month. The September collection showed an increase in the ratio nearly

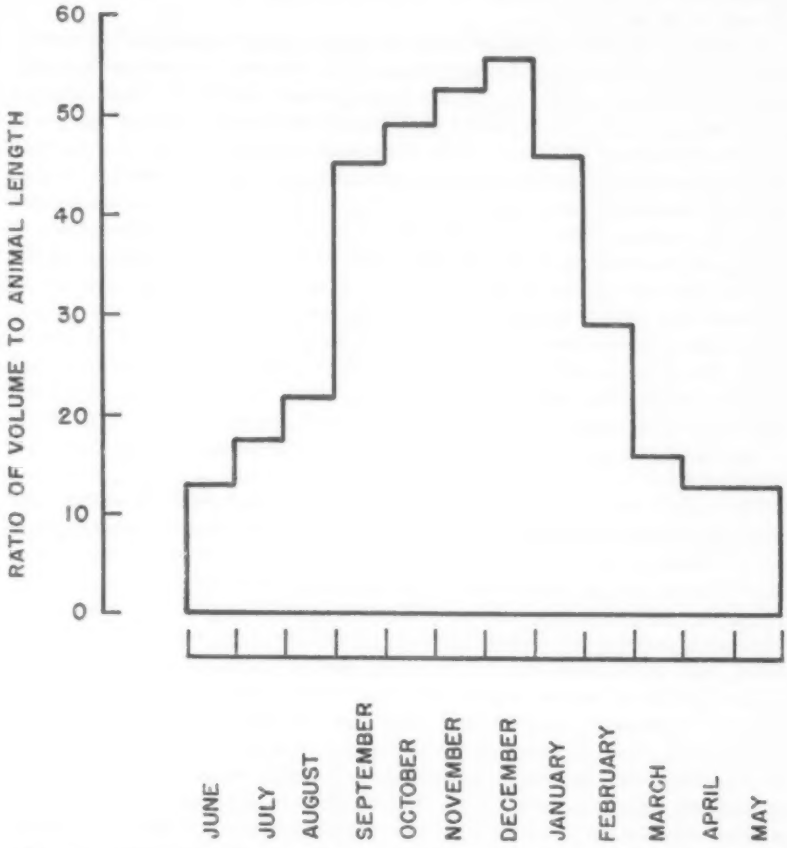

FIG. 1.—Seasonal variation in ratio of volume of testis to total length of adult and yearling bucks in South Texas.

double that for August. Smaller increases occurred in October, November, and December, with the peak in December.

The January collections showed a marked decrease, nearly to the level of the September-taken specimens. About the same magnitude of decrease occurred in February and March, then a slight decrease from March to the April, May, and June level.

Standard histological sections, 15 microns thick, were prepared from the piece of tissue removed from one of each pair of testes in the field, stained with haematoxylin and eosin, and then examined for presence or absence of sperm. A calibrated ocular micrometer for a microscope was used to determine the diameter of the seminiferous tubules, using the average of ten measurements for each of 39 specimens.

In order to determine what relationship, if any, exists between the volumetric changes of testes and the average diameter of tubules, the average monthly ratios of testicular volume to tubular diameter were calculated. These average ratios have a correlation coefficient of 0.95 with the average ratios of volume of testis to total length of animal. In the absence of experimental evidence showing that increase in size of testis is primarily caused by increase in diameter of tubule, the high correlation figure indicates only that for corresponding periods in time when the volume of the testes changes, the diameter of the tubules tends to remain about constant. Thus, the magnitude of change of the diameter of the tubules does not appear to be sufficient to account for the large variation in testicular size from breeding to non-breeding season.

Field observations of male activity.—During the study period, Dr. W. B. Davis, R. B. Davis, and I kept records of observations of the physical conditions and behavior of deer that might reflect sexual activity. The records of collections made on monthly trips to the study area and those records made by R. B. Davis during his period of full time field study (June, 1948–June, 1949) provided the following data.

The earliest date on which a collected specimen had shed his antlers was February 5 (1949 collection); March 30, 1950, was the latest date for a specimen with a full set of antlers. There were no records of males with shed antlers prior to February 1, nor of males with antlers of the previous season after April 30. On May 1, 1949, an adult male was collected that had recently shed his antlers. I believe that the above-stated time span rather accurately covers the period in which most adult males in the study area shed their antlers.

Development of antlers begins very early in the year in fawns, the earliest record of a specimen having small nubs was on January 7. Development in adults begins later, of course, as the new growth begins about two to six weeks subsequent to the shedding of antlers (Asdell, 1946). Small nubs were present on an adult male collected on April 13, 1949. Prior to this date, males with shed antlers exhibited no new antler growth, showing only a scab-like appearance of the pedicel. The latest date on which an adult had only small nubs was May 6. By June 3 (1949 collection) the antlers were forked and by the first week in August most of them had two or more points.

Wislocki, *et al.* (1947) pointed out that the development and shedding of antlers are under the influence of both pituitary and gonadal hormones. Experiments conducted by Wislocki and his colleagues indicate that antler development is probably activated by a hormone or a hormone complex from the anterior pituitary because their period of development occurs when the testes are nearly minimal in size and activity. The increase in testicular activity as

fall approaches seems to be the factor necessary for the secondary calcification of antlers and the shedding of velvet. The shedding of antlers appears to be under the influence of a decreasing level of gonadal activity and the increasing effects of pituitary activity. Table 1 denotes the relationship between testicular volume as an indication of sexual activity and the condition of the antlers observed each month.

Usually, observers do not recognize rut until it is obvious that bucks are running with does, following or chasing them, or exhibiting interest in places where does have urinated. In 1948 this first became evident on October 13 and 14, when Richard Davis saw bucks with a herd of does exhibiting interest in doe urine. However, Table 1 shows that an increase in testicular volume had begun at least a month earlier. It is possible that during September the rise in testicular activity had not overcome the inhibiting effect of anterior pituitary secretions. Perhaps, therefore, the stimulus to breed comes only as the effects of the androgenic hormone accumulate, which may require about a month for accomplishment. The cause for the time lag between seasonal gonadal development and sexual interest is a question deserving further study.

Laboratory analysis of female reproductive tracts.—Ovaries provide more positive information about the sexual condition of the animal than do the testes. Not only is it possible to recognize the condition occurring when the animal is collected, but an estimate of past performance can be made without microscopic examination. Cheatum (1949) developed a technique whereby gross observations can be used, with a corollary factor, to estimate the number of young produced during the previous breeding season. In Cheatum's study, it was found that corpora lutea of pregnancy acquire a pronounced pigmentation while regressing after parturition. The regressing corpora of the estrus cycles do not.

Cheatum (*op. cit.*) states, however, that gross observations of corpora luteal scars of pregnancy are not reliable indicators of ovulation incidence beyond the succeeding gestation period. The data on incidence of ovulation and frequency of fertilization derived from the specimens collected for this study are summarized in Table 2.

The ovulation incidence is the average number of corpora luteal scars per female during a particular gestation period. The fertilization frequency is the ratio of pregnant to nonpregnant females collected during the breeding period. The ovulation incidence multiplied by the fertilization frequency gives an estimation of the previous fawn production per female. The estimated previous production by females for the breeding season of 1947–1948 is shown in Table 2.

A comparison of the estimated productivity with embryo counts should reveal the limits of accuracy of the estimate. As shown by Table 2, this appears to be the difference between 1.41 and 1.28 young per female.

These two figures, 1.41 and 1.28, are not directly comparable, however, and cannot be used for checking the reliability of the estimated production. Since no better indication of productivity is available from this study, it seems probable that the actual productivity lies within the range of 1.28 to 1.41 young per female.

Applying the formula expressed by Kelker (1947) $r = (1-fy)$, where r is the rate of increase, f is the sex ratio, and y is the average number of young per adult female, the range of the rate of increase on the study area appears to be from 64 to 70 per cent annually. This is assuming an even sex ratio in adult deer, but does not take into account fawn mortality. Further study is needed to ascertain the actual rate of increase of these deer herds.

Because one of the primary objectives of the study was to determine the period and extent of the breeding season, it became necessary to determine the approximate ages of embryos. Since the only available data are those published by Cheatum and Morton (1946) on embryos recovered by autopsy or Caesarian section a known time after copulation, a regression coefficient was calculated for

TABLE 2.—*Ovulation incidence, fertilization frequency, and estimated previous productivity of breeding age female whitetail deer collected January 1 to May 3, 1949, and January 1 to March 8, 1950*

	1949	1950	TOTAL	RATIO OF TOTALS
Number collected	28	12	40	
Number pregnant	21	11	32	
Frequency of fertilization (per cent)	.75	.92		.80
Number of embryos	29	12	41	
Males	16	3	19	1.36:1
Females	9	5	14	M to F
Undeterminable	4	4	8	
Number with corpora luteal scars	17	8	25	
Number of corpora luteal scars	28	16	44	
Ovulation incidence	1.65	2.0		1.76
Average productivity per pregnant female	1.38	1.09	1.28	
Calculated average number of fawns per female in previous gestation period	1.24 (1947–48)	1.84 (1948–49)		1.41

their data. Using standard statistical methods, the estimated ages for embryos collected during this study were determined. The standard error of estimate was calculated to be ±5 days. Table 3 shows the calculated approximate conception date of the 41 embryos recovered from our specimens.

A summarization of the approximate conception dates into 10-day periods provides a range of time that includes all the error of estimate of calculation. As the starting point for these periods, five days prior to the earliest calculated date of conception was used. The largest percentage of the number of females bred in a 10-day period indicates the peak of the breeding season, which in this study was from December 15 to 24. Figure 2 gives a graphic illustration of the breeding season. According to these data, the season when females are capable of reproduction is from about the middle of November to the first week in February. The data further indicate that the period from the middle of December to the first week of January encompasses the main period of breeding in females.

Examinations of specimens to determine age revealed that there is apparently no breeding by female fawns. This is contrary to the findings in New York (Cheatum and Morton, 1946; Morton and Cheatum, 1946, 1950), where as many as 36 per cent of the fawns were pregnant in areas of good deer range. The correlation found by Cheatum (1950) between range condition and incidence

TABLE 3.—*Estimated breeding dates of South Texas whitetail deer based on embryo lengths and dates of collection of females*

COLLECTION DATES IN CHRONOLOGICAL ORDER	EMBRYO LENGTH IN MM.	ESTIMATED EMBRYO AGE IN DAYS	CALCULATED APPROXIMATE DATE OF CONCEPTION
January 10, 1949	11	32	December 9, 1948
February 5, 1949	14	34	January 2, 1949
February 5, 1949	38	43	December 24, 1948
February 7, 1949	52*	48	December 21, 1948
February 7, 1949	12	33	January 5, 1949
February 23, 1949	56	49	January 5, 1949
March 5, 1949	129	75	December 20, 1948
March 5, 1949	138*	78	December 17, 1948
March 6, 1949	129	75	December 21, 1948
April 1, 1949	220	107	December 15, 1948
April 1, 1949	205*	102	December 20, 1948
April 2, 1949	265	123	November 30, 1948
April 13, 1949	221*	107	December 27, 1948
April 15, 1949	245	116	December 20, 1948
April 18, 1949	246	116	December 23, 1948
May 5, 1949	328	145	December 11, 1948
May 6, 1949	279	128	December 29, 1948
May 6, 1949	324	144	December 13, 1948
May 6, 1949	340*	150	December 7, 1948
June 3, 1949	416*	176	December 19, 1948
June 3, 1949	394*	169	December 16, 1948
February 3, 1950	13	34	January 1, 1950
February 3, 1950	49	47	December 18, 1949
February 4, 1950	13	34	January 2, 1950
March 2, 1950	8	32	January 29, 1950
March 2, 1950	77	56	January 5, 1950
March 2, 1950	118	71	December 21, 1949
March 3, 1950	101	65	December 28, 1949
March 4, 1950	125*	73	December 21, 1949
March 4, 1950	55	49	January 14, 1950
March 8, 1950	93	62	January 5, 1950
March 8, 1950	116	70	December 28, 1949

* Average of twin embryos.

of breeding by fawns indicates that studies of range conditions for deer use might reveal a partial explanation for both the negative incidence of fawn breeding and the relatively low production of young per adult female in southern Texas.

Field observations of female activity.—Evidence of sexual activity in females in the field is not so conspicuous as in males. The only obvious display of interest

lies in the more passive response of a doe to the persistent attentions of a buck, including little or no resistance to attempts at copulation. Also, the does seem to urinate more frequently on the metatarsal glands which become caked with

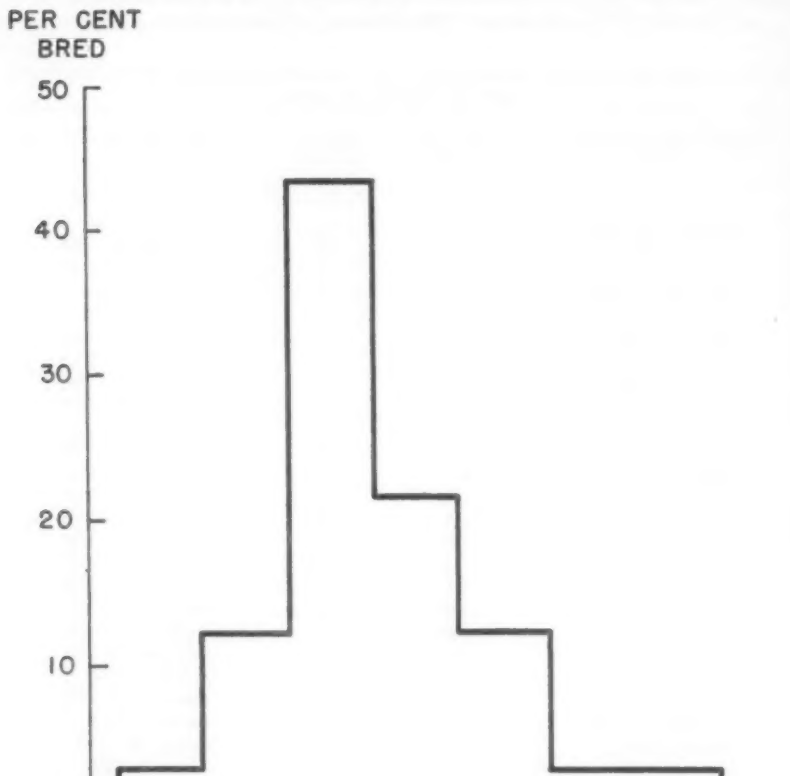

FIG. 2.—Seasonal distribution of breeding in South Texas whitetail deer, based on embryo development.

a vile-smelling substance. Interest of a male in a particular female seems to be better evidence of the stage of her sexual cycle than are any of her mannerisms or external characteristics.

Observations on reproduction of females collected from July through December are of interest. Those adults collected on July 6, 1949, had large cotyledons, flabby uteri, and distended cervices. Also, two specimens had fresh blood clots on the cotyledons. This indicated that parturition had probably occurred but a few days earlier, perhaps even the previous day. One of those collected had a female fawn in attendance. The unsteady walk, small size (7½ pounds, 26 inches total length), and long remnant of the umbilical cord indicated that the fawn was only a few days old.

Opinions as to the length of the gestation period in whitetail deer range from records of 189 days (Cheatum and Morton, 1946) to an estimate of 212 days (Taylor and Davis, 1947). Asdell (1946) states it to be about seven months, Nichol (1938) believes it to be about 200 days, while Cheatum (1949) reports it is about 196 days in New York. These reports average 202 days. Nichol (1938) found that in captive mule deer, the length of the gestation period tended to remain nearly constant for an individual. Thus, with a total range of variation possible from 189 days to about 212 days, estimates of the breeding dates of does with newborn fawns could be expected to be accurate only within a three-week period. With a mean of about 200 days for the gestation period, these does which had recently given birth and were collected on July 6, 1949, must have conceived about the middle of December.

The uteri of post-partum females remained remarkably flabby and distended until the December collections. In none of the animals collected did the ovaries have follicles near maturity, nor was a corpus hemorrhagicum ever found. Despite the evidence that breeding begins in November, embryos were not found until January, but they were then at least 30 days old. According to Cheatum and Morton (1942), embryos about four millimeters long are the smallest likely to be detected on autopsy. This is a little more than one-half the size of the smallest embryo recovered in this study.

Further evidence, which supports embryo data, for determining the breeding season is the sight record of fawns. In Kenedy County, no fawns were seen by R. B. Davis and me during the collecting trip made in the first week of June, 1949. On the next trip in the first week of July, 1949, we saw many fawns and one (referred to above) was collected. Questioning of ranch personnel revealed that they had seen no fawns prior to June 15. This, of course, does not indicate that none was born before June 15, but certainly fawns were not as obvious as they were in July. In August it was difficult to determine the proportion of fawns that were very young because by that time all of them could move with ease. Counting backwards six and a half to seven months again puts the main period of conception in December.

Conclusions.—Comparison of the data that depict the breeding season for females with the height of gonadal activity in males leads to the conclusion that there is a synchronization between the peak of the rutting season for males and the peak period for numbers of receptive females. This coincidence of peaks may be a normal condition as the herd on the area studied undergoes practically no losses from hunting and the sex ratio approaches one male to one female.

The length of time in which does come into heat governs the breeding season entirely. There is no doubt that bucks are capable of breeding long before any does have ovulated and long after the last one has experienced an estrus cycle. Therefore, the cause for differences in breeding season can be determined only by discovering what governs the time stimulus for does. Morton and Cheatum (1946) postulate nutritional causes related to range condition as a possible factor governing fertility. This may also have an effect on the periodicity of breeding in females. Wislocki (1943) suggests that although the cycle is initiated by light the onset of rut is influenced by decreasing daylight.

The primary sex ratio, as indicated by embryos found in females collected during two breeding periods (Table 2), was 1.36 males: 1 female. Eight of the embryos had not developed sufficiently to determine sex. Of the other 33, 19 were males, 14 females. This is perhaps too small a sample on which to base

TABLE 4.—*The probable month of birth of whitetail deer fawns based on age estimated by the stage of tooth development*

NO. AND SEX	DATE COLLECTED	AGE ESTIMATE	PROBABLE BIRTHDATE
159 M	9–26–49	8 wks.	7–15 to 8–15–49
27 F	9–23–48	10 wks. to 3 mo.	7–48
150 F	8–1–49	7–10 mos.	10–48 to 1–49
47 M	11–2–48	4–5 mos.	7–48
170 M	10–28–49	4–5 mos.	6–49
152 M	8–2–49	10–11 mos.	9– to 10–48
155 F	8–3–49	11 mos.	9–48
164 F	9–23–49	11 mos.	9–48
174 F	11–25–49	11½ mos.	11–48
154 M	8–3–49	11 mos.	9–48
31 F	9–24–48	13 mos.	8–47
176 F	11–25–49	13 mos.	6–48
29 M	9–23–48	15 mos.	6–47

a sex ratio. The chi-square test reveals that the ratio is not significantly different from 1:1.

Direct application of the age estimate technique outlined by Severinghaus (1949) indicates that for South Texas deer his method cannot be used with reliance. Table 4 gives the estimated month of birth for 13 fawns collected as specimens. The jaws from these specimens were sent to Mr. Severinghaus for verification of my age determinations. In three specimens—numbers 155, 164 and 31—the ages estimated by me differed two to five months from those assigned by Mr. Severinghaus. The ages in the table are those assigned by him. The embryo data and our field observations do not support the indication that fawns are born from October through January, as would be the case for numbers 150 and 174.

Summary.—For South Texas whitetail deer, analysis of 96 female reproductive tracts and 41 embryos indicates that the breeding season is from November to February, with the peak from December 15 to January 3. Breeding success

during 1949 and 1950 was approximately 1.28 fawns per pregnant female. There was no evidence that fawns breed during their first winter. Bucks begin to show signs of sexual activity in September and seemed to be reproductively virile until early February. Most antlers were shed during February and March. Variations in the diameter of seminiferous tubules apparently do not contribute an important amount to variations in testicular size. Age determination by eruption and amount of wear on dentition needs further study and verification before the method can be used with reliance.

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FOOD HABITS OF THE RACCOON (*PROCYON LOTOR HIRTUS*) IN NORTH-CENTRAL MINNESOTA

By Lyle J. Schoonover and William H. Marshall

The food habits of raccoon have been studied in several eastern and southern states, but little is known about this subject under Minnesota conditions. This paper presents data obtained during the summers of 1948 and 1949 while carrying on a field study of movements and populations of raccoon at the Rice Lake National Wildlife Refuge, which is located in the north-central portion of Minnesota. Intensive live trapping, tagging, and tracking were conducted on four areas, each containing approximately 1000 acres, located in the Refuge. Other parts of the Refuge and the surrounding farms were also visited from time to time. The Refuge lies near the northern extremity of the raccoon range in this part of the state.

The authors wish to express their appreciation to the Refuge Division of the U. S. Fish and Wildlife Service for co-operation in providing quarters and other facilities at Rice Lake. Messrs. Karl Kobes, Frank Martin and Francis Gillette were particularly helpful throughout the field work.

Method.—Each summer, when the study began, fresh scats along the trap line were collected and the old ones were destroyed. By keeping a constant watch for scats on the trap line, many of them were collected before they were a day old. Scats were also collected from traps where it was evident that the scat did not contain any of the bait used in the trap.

The materials collected were spread over a newspaper and thoroughly air dried. Occasional stirring prevented lumping and sticking to the paper. Each food item of the dried material was then separated and measured in a graduate of either 10cc. or 100cc. capacity, depending upon the quantity to be handled. To get uniform compaction, the bottom of the graduate was gently tapped with the palm of the hand. The "percentage of volume" as used in this paper was calculated by dividing the volume of each item by the total volume of all the items. The "frequency of occurrence" was calculated in the same manner.

Reliability of data.—Scat analysis can give valuable information as to food preferences and seasonal dietary changes, but the limitations of this work must be realized. The first limitation comes with the investigator's ability to recognize the scats sought.

A second limitation is recognized in the analysis of the scats. Neither the volume measurement nor frequency of occurrence gives a true picture of the food habits of the animal. Bulky foods such as crayfish and plums are over emphasized in a volume measurement. On the other hand, items taken frequently in small amounts, such as beetles, are misrepresented in frequency of occurrence tabulations.

Still a third error is believed to be present in the food habits study. It was noticed early in the study that frog bones and beetle fragments were frequently found in the same scat. Upon examination of 21 leopard frogs (*Rana pipiens*), such items as crayfish, beetles, flies, grasshoppers, bees, mosquitoes, and tadpoles

were found in their stomachs. A frog fed dytiscid beetles was in turn fed to a captive raccoon. The resulting scat contained frog bones and beetle fragments similar to those in scats collected in the wild. What proportion of the beetles are taken in this manner is not known.

It is also quite possible that some fully digested foods were entirely omitted from the food list. It is suspected that a considerable number of mud turtle eggs were taken in July, but no evidence of this fact was found in the scats.

TABLE 1.—*Food items recorded in 135 scats collected in the summer of 1948 and 1949*

FOOD ITEM	PER CENT OF VOLUME	FREQ. OF OCCURRENCE IN PER CENT
Crayfish (*Cambarus virilus*)	31.0	23.2
Juneberries (*Amelanchier* spp.)	26.8	12.6
Grasshoppers (*Melanoplus* spp.)	10.5	9.2
Acorns (*Quercus* spp.)	8.0	5.5
Debris	5.7	5.8
Meadow voles (*Microtus pennsylvanicus*)	2.7	5.1
Plums (*Prunus americana*)	2.6	3.4
Raspberries (*Rubus* sp.)	2.5	2.0
Chokecherries (*Prunus virginiana*)	2.2	1.7
Fish: buffalo (*Megastomatobus cyprinella*) and bullheads (*Ameiurus* spp.)	1.7	4.1
Beetles: diving beetles (Dytiscidae), water scavenger beetles (Hydrophillidae), giant water bugs (Belostomatidae), and ground beetles (Carabidae)	1.0	11.6
Oats (*Avena* sp.)	1.0	.3
Pincherries (*Prunus pennsylvanica*)	.8	2.0
Corn (*Zea mays*)	.7	2.0
Passerine birds	.5	2.0
Muskrats (*Ondatra zibethica*)	.4	.3
Bees (Hymenoptera)	.3	1.0
Frogs (*Rana pipiens*)	.2	2.0
White footed mice (*Peromyscus* sp.)	.1	.3
Clams (Unionidae)	.1	2.0
Grass	.1	1.0
Butternuts (*Juglans cinerea*)	trace	.3

Food habits data.—Between June 14 and September 10, 1948, fifty-six scats were collected. Between June 22 and September 12, 1949, seventy-nine more were added to the collection, making a total of 135.

As shown by Table 1, one of the most striking characteristics of the raccoon's food habits is the great variety of items taken. It will be noticed that 27 different items, not counting the various families of beetles and fish, were identified in the scats. Crayfish, juneberries, grasshoppers, and acorns were taken in the greatest quantity; together these items account for 76.3 per cent of the total volume. Beetles appeared in the scats frequently throughout the summer, but no scats were entirely made up of these insects, and as a rule, fragments of only one or two individuals were present in a scat.

Relationship between availability of food and food habits.—Phenological data were recorded throughout the two summers. Notations were made as to the dates when various foods became available and when they disappeared, as well as a rating of their abundance. Crop abundance was rated as very good, good, fair, and poor, based on the quantity present and the ease with which raccoon could obtain it.

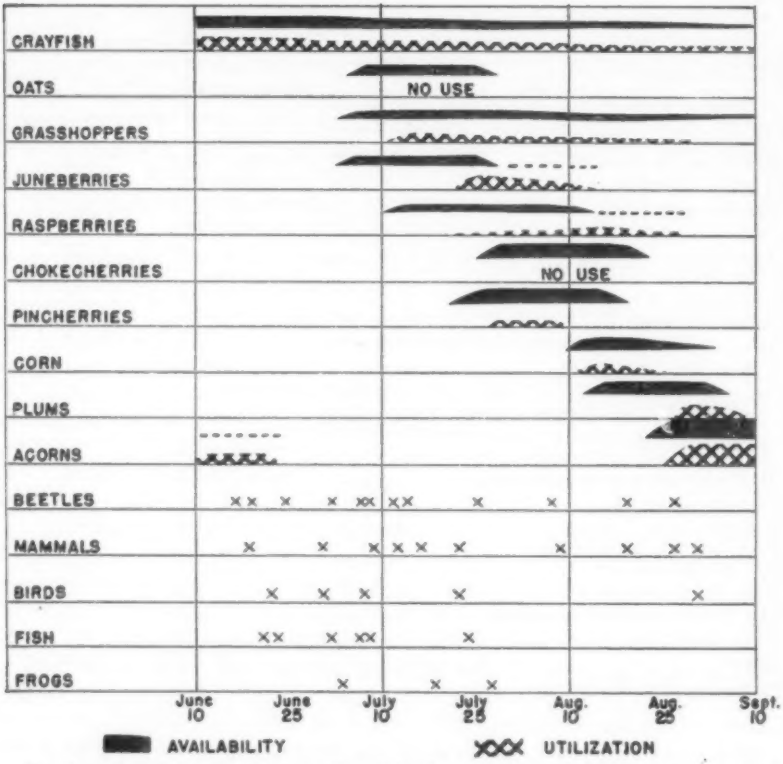

FIG. 1.—The relationship between the utilization and the availability of raccoon foods in 1948. The period of utilization, in this and in Fig. 2, in some cases exceeds the period of availability because; (1) raccoons sometimes found items that were no longer available in the sample plots under observation, and (2) the scats were sometimes not found for several days.

On the basis of food availability, the summer was divided into three periods, corresponding roughly to the pre-berry period (mid-June through July 10), the berry period (July 10 through August 10) and the post-berry period (August 10 to mid-September).

During the first period the greatest activity was noted along the river banks and barrow pits. Scats found in this habitat were made up almost entirely of

crayfish exoskeleton. As evidenced by raccoon tracks, both the crayfish in the water and those burrowed in the mud are taken by raccoon. Frequently, burrows were found which had been slightly enlarged by raccoon to a depth of from three to seven inches. From the appearance of the excavations it seems that the raccoon thrust a front foot into the burrows and seek out crayfish by feeling for them. Swimmerets, pincers, and bits of exoskeleton remained near the burrows

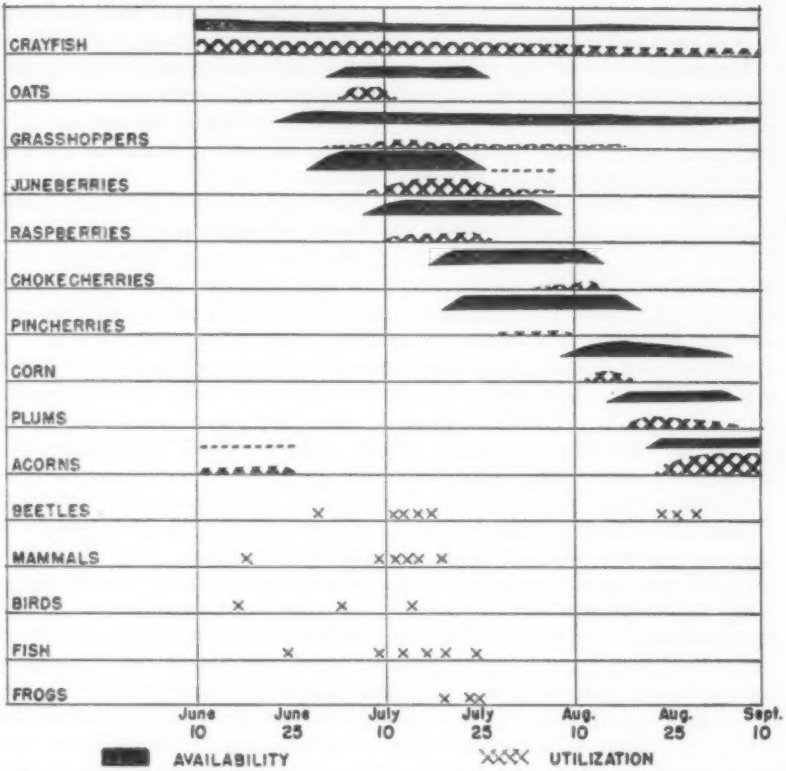

FIG. 2.—The relationship between the utilization and the availability of raccoon foods in 1949.

where successful captures had been made. On other occasions crayfish remains were found near the water with no sign of a burrow nearby. In such cases the crayfish were probably taken out of the water. As shown by Figures 1 and 2, the consumption of crayfish increased with an increase in availability.

A few scats collected from the upland in this period contained oats, acorns, parts of birds, small mammals, frogs, immature grasshoppers, and a variety of other insects.

The second period (July 10 to August 10) corresponds to the height of the

"berry season." Juneberries are the first of the summer fruits to mature, followed by raspberries, pincherries and chokecherries. Raccoon apparently find juneberries to be very palatable and seem to prefer them to other wild fruits. For some unknown reason there was an interval of 12 (1949) and 20 (1948) days between the time the berries ripened and the time they appeared in scats. After "'coon sign" once appeared at the bushes under observation, there was evidence of return trips on nearly every successive night until the bushes were bare. Even after the juneberry season, when only a few dried berries remained on the bushes, fresh scats made up entirely of juneberries were frequently found.

The juneberry yield was reduced in 1948 by late spring frosts and an early dry period. The following year the bushes were heavily loaded with berries. This difference in abundance was reflected in the food habits of the raccoon. The percentage of juneberries in the diet during this period rose from 28.5 per cent in 1948 to 44.5 per cent the following year.

Raspberry, chokecherry, and pincherry bushes grew in close proximity to the juneberry bushes and were judged to be just as plentiful. As shown in Figures 1 and 2, these fruits play a minor role in the food habits of the raccoon. As a rule, they were eaten in the greatest quantities after most of the juneberries were gone. Currants and gooseberries were also plentiful on the uplands, but they are apparently not among the preferred foods of raccoons.

Crayfish were still taken, but the number of tracks seen along the river during this second period was greatly diminished. The scats found there frequently contained a mixture of juneberries and crayfish. Apparently part of the night's hunting activities was spent on the upland, as juneberries are not found on the lowlands adjacent to the river.

Mammals, birds, fish, and frogs were taken most frequently before the first of July. Although the availability of these items could not be determined, it is believed that they were just as plentiful later in the summer. Apparently these items are taken in the greatest quantities when there is scarcity of other foods.

By the third period of the collection (August 10 to mid-September), the preferred fruits were less abundant. There was a noticeable shift of activity from the berry patches to the early cornfields. Sweet corn reached the milk stage a week to ten days ahead of the other corn, and it was in these fields that the first activity was noted. The three fields under observation were visited by raccoon each night until the corn began to harden. There was no evidence that raccoon feed on mature corn or on corn that developed later in the season. Activity in the cornfields suddenly ceased in both years about August 25, when scats containing acorns began to appear. The consumption of acorns increased until September 1, at which time they constituted approximately 90 per cent of the scat volume. The mast crop of the fall of 1948 was unusually heavy. Acorns could still be found the following spring, and as shown in Figure 2, they were taken by raccoon until mid-June.

Relationship between habitat and food habits.—Area I contains approximately 1000 acres of bottomland along the Rice River. The lowering water level in the barrow pits and river, during the summer, leaves a mud bank free from vegetation. It is along these banks that raccoon hunt for crayfish, which live in the

shallow water under leaves and sticks or in burrows on the bank. This area has a plentiful supply of frogs, crayfish and beetles, but grasshoppers and berries are scarce.

Area II contains approximately 1000 acres of upland, about one and one-half miles from the river. Within this area nearly all of the wild fruit-producing shrubs native tf the region are represented. Juneberries, pincherries, blackberries, raspberries, chokecherries, wild plums, and hawthorns are present and produce fruit. In this area grasshoppers, berries, mice, and small grains are readily available. Crayfish are either scarce or entirely absent.

A comparison of the scat collections taken from the two areas (Table 2), and an analysis of the fecal material of marked animals, suggests that the food habits of raccoon vary with the habitat in which they live. In the scat collection from the bottomland habitat crayfish accounted for nearly two-thirds of the

TABLE 2.—*Food items recorded in the two contrasting areas*

AREA I (49 SCATS)		AREA II (45 SCATS)	
Food Item	Per Cent by Vol.	Food Item	Per Cent by Vol.
Crayfish	66.5	Juneberries	44.2
Juneberries	15.0	Grasshoppers	22.8
Acorns	7.0	Acorns	5.8
Oats	3.0	Mammals	5.1
Mammals	1.5	Corn	4.9
Beetles	1.4	Chokecherries	4.8
Raspberries	1.2	Raspberries	4.5
Fish	.9	Fish	3.0
Waterfowl	.8	Pincherries	1.7
Frogs	.3	Crayfish	.9
		Frogs	.2

volume. Approximately 82 per cent of the total volume was of lowland origin. Within this area one animal, 'Coon No. XIII, was captured three times, and his tracks, which could be identified by a clipped toe, were observed 20 times. Five scats in the collection can definitely be ascribed to this animal. They contained crayfish (138 cc.), beetles (5 cc.), mammals (8 cc.), and fish (1 cc.).

In the upland habitat (Area II), nearly one-half of the scat volume was made up of juneberries. Approximately 96 per cent of the total scat volume collected in this area was of upland origin. At the same time as 'Coon No. XIII was studied in the bottomland habitat, another animal, 'Coon No. V, was captured four times and tracked three times on the upland. Four scats which were known to belong to this animal contained grasshoppers (121 cc.), chokecherries (84 cc.), juneberries (11 cc.), pincherries (6 cc.), mammals (5 cc.), and plums (1 cc.).

The data just presented suggest that some raccoon spend most of the summer on the upland and feed to a large extent on grasshoppers and berries. Other individuals apparently do most of their feeding in the lowland on crayfish and make occasional visits to the uplands in search for berries and small grains.

From the chemical composition of grasshoppers and crayfish it would seem

that one could be easily substituted for the other in the diet. McHargue (Jour. Agric. Res., 10: 633–37, 1917) gives the dry weight composition of grasshoppers as follows: protein, 75 per cent; fat, 7 per cent; and ash, 6 per cent. Presumably most of the remaining 12 per cent is comprised of carbohydrates and chitin. An analysis of the ash indicated that grasshoppers are a rich source of phosphorous and potassium. Since no comparable data could be found for the North American crayfish, an analysis of a closely related European form will be used for a comparison. Kükenthal and Krumbach (Handbuch der Zoologie, 1927) give the dry weight composition of the genus *Nephrops* as follows: protein, 52 per cent; fat, 3 per cent; carbohydrate, 3 per cent; chitin, 7 per cent; and ash, 34 per cent. Phosphorous and potassium are both present in the ash.

Summary.—This study indicates that "availability" determines, to a large measure, the foods eaten by raccoon. Changes in food availability, due both to the progress of the season and differences in habitat, are reflected in the food habits. Early in the summer crayfish constitute approximately three-fourths of the fecal material. By midsummer wild fruits are available and become dominant in the diet. At the close of the "berry season" a shift is made to corn and acorns.

The data also suggest that the summer diet of raccoon living on the upland consists predominantly of grasshoppers and berries, whereas raccoon living in the lowlands feed chiefly on crayfish.

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GORILLA CENSUS AND STUDY

By Robert M. Yerkes

This report is being written because, of all the types of animal I have observed naturalistically or used in experiments during almost sixty years of work as psychobiologist, none has so stirred my curiosity and suggested so many questions as the gorilla. Whether we deem it success or failure, it is one of Nature's impressive experiments in primate evolution, which probably nears its end. For reasons which will appear, this is a plea for more and better gorilla study—at once more inclusive and intensive, more persistent and imaginative, more critical and enlightening. For of all that might profitably be learned about the animal, and all that it might help us to discover, little has yet been recorded. And for it, if not for us, time is running out.

Presumably, in a pre-scientific period of unknown duration, gorillas were known to African natives and some Europeans, but from this period no useful records have come to us. It is only a century since they were discovered to scientists by the missionaries Savage and Wilson (1847). Since then the genus *Gorilla* has been established, with two species and a number of races currently recognized (Coolidge, 1929). Beside many popular contributions, an extensive scientific literature has accumulated. Unfortunately, it is factually thin, fragmentary, repetitious, and extremely variable in quality because often based on poorly preserved, insufficient, or otherwise unsatisfactory materials, or on the observation of specimens of unknown age, developmental stage, life-history, and condition. Many contributions are difficult to evaluate.

In 1896, the British anatomist-anthropologist, Arthur Keith, published a synoptic account of what then was known about the anthropoid apes. His chapter on the gorilla includes a list of about a hundred scientific reports of which the majority deal with general appearance, habits, and anatomy. The frequency of publication has increased during the last half century, and beside me is a bibliography which includes several hundred titles. Nevertheless, for such major areas of biological science as morphology, physiology, and psychology, the adequacy and dependability of our knowledge vary extremely.

Alike in quantity and quality, morphology easily ranks first, yet even today the gross anatomy of genus and species, versus individual, is imperfectly known. Comprehensive descriptions are few. Deniker (1885) described with admirable care a foetus, supposedly in its fifth or sixth month of development. Contemporary research and the status of knowledge of gorilla structure are best represented by the recently published monograph of Raven (1950) which, with all its merits of original contribution and splendid illustrations, fails to exhibit relations to the work of other investigators and to present an inclusive bibliography. But surely morphology should begin, not end, with gross anatomy! Incredible though it may seem, of gorilla histology, embryology, and structural genetics very little is known (Schultz, 1927). Even the number of chromosomes is a matter of surmise.

As for physiology, the situation is extremely disappointing. There are some

islands of fact in a vast sea of ignorance. Gorilla life history has not been observed and described; even the sexual and the reproductive cycles are incompletely and uncertainly known, and no useful description of either exists. Few specimens have been reared from infancy to sexual maturity, and none has yet been bred under controlled conditions of mating and gestation. For physiological science the gorilla is virtually an unknown organism, because it has rarely been available as an experimental animal.

Despite many titles which seem to indicate otherwise, the psycho- and sociobiology of the king of living anthropoids are unexplored areas. The naturalistic literature on habits, customs, and social relations, although abundant, is unsatisfactory because episodic, and more often entertaining than convincing and reliable. And significant experimental studies of behavior and mental traits and capacities may be counted on one's fingers. Gorilla psychobiology is yet to emerge as a significant extension of knowledge.

Reluctantly one admits that this extraordinarily intriguing type and genus, after a full century of availability to biologists, is still superficially, incompletely, and wholly inadequately known. Why? And why the surprisingly slow progress of gorilla study during a century—1850 to date—when natural science has flourished exceedingly?

Neither now, I am sure, nor at any time during the century could lack of interest, curiosity, and adventuresomeness among biologists be offered as a major explanation of slow progress. There evidently are other reasons, among which the following seem to me most influential. (1) Within our knowledge, *Gorilla* has not been widely distributed or abundant. Confined to a narrow strip of equatorial Africa, it is almost as slow breeding, probably, as man—12 to 15 years for a generation—, and it seems improbable that at any time more than a few thousand have been in existence. (2) Naturally suspicious, wild, timid and wary, and never savage and aggressive save defensively, they are difficult to capture uninjured except when very young and by destruction of parents. Because of their striking resemblance to man, white hunters and, to a lesser degree, African natives have been reluctant to kill them for sport. (3) If captured in infancy they prove relatively difficult to feed and maintain in health, and require intelligent and devoted care, and if captured as adolescents or adults they rarely can be kept alive and tamed. (4) Finally, and this may be a chief deterrent, throughout the century of which I write they have been very costly, as well as rare, in Europe and America. Whereas the market price of live chimpanzees is measured by hundreds of dollars, that of gorillas is measured by thousands. I am told that the current price in New York is $3000 to $5000. But, for a perfect specimen I have been asked as little as $5000, as much as $20,000. Not many biologists can afford such expensive research subjects.

Beginning in the 1850s, skulls, skeletons, skins, and exceptionally a preserved specimen began to reach the museums and biological laboratories of various countries. Occasionally a live specimen, usually young and in poor condition, arrived in Europe or America, but during the nineteenth century they were rare and seldom survived more than a few months. In fact, prior to this century, it

seems improbable that more than a score had reached America alive, and from meager records I estimate that between 1850 and 1950 the number imported does not exceed one hundred. Whereas in the early years owners had poor luck in caring for the animals, in this century, and especially during the last twenty-five years, success has increased rapidly. At long last we are learning how to keep them in health and contentment and to rear them to adulthood. Several American zoological gardens have kept individuals for many years. Bamboo has been in the Philadelphia Zoo about 24 years and Massa about 16 years. At the San Diego Zoo two fine males were successfully kept as exhibits nearly 12 years. Similarly, at the Bronx Zoo in New York, Oka has lived for 10 years, and Makoko died by accident after 10 years. Two females in the Central Park Zoo, New York, have been on exhibition 8 years. And in the Lincoln Park Zoo, Chicago, the huge male, Bushman, died after 21 years.

Recently two circumstances have notably encouraged and facilitated the importation of young gorillas for sale in America—the agricultural development by recent immigrants of portions of the gorilla's West African habitat, and transportation by air. The slaughter of adults to protect crops has enabled settlers and natives to capture many dependent infants and youngsters under five. Collectors snap them up at small cost for export, and overnight by air express they appear in New York or some other foreign market. Thus, in the last few months gorillas have arrived safely and in unprecedented numbers on our shores.

According to a report published in 1949 by Riess *et al.*, there were then 25 gorillas in the United States, of which half were adolescents or adults. The report lists 22 by name and location. Three of these, all adult males, have since died. This census supports the statement that success in keeping and rearing the animals has increased markedly.

Especially because of the recent influx of infants, I have made a new census and survey of our gorilla population. As of June 2, 1951, it is almost twice as great as in 1949. At this rate of increase we should soon be seriously overpopulated, and embarrassed by an unexpected wealth of scientific materials. Young specimens are especially useful because they can readily be handled as subjects of experiments, whereas adults cannot. A new era of gorilla study began with 1950, an era of opportunity which should become one of achievement.

It has seemed desirable in this census report to identify each individual by name and present location, to give the name of the owner or responsible official, to designate the species (race is impracticable), and the date of receipt by the present owner. I thus indicate my indebtedness to them for information and my appreciation of their co-operation. Naturally I hope that this report may help to extend their acquaintance with neighboring research biologists and lead to mutually agreeable and profitable co-operation. I had hoped to state also the birthplace or region of capture, but this information proved so indefinite or uncertain that it has been omitted. From the scanty data available, and in consultation with the owner, I have chosen a *hypothetical* birth-date for each individual. Although, in some instances, this may be in error by six months, it should prove a better basis for indicating age than that ordinarily used.

TABLE 1.—*Census of gorillas in the U.S.A., 1951*

LOCATION	NAME	SPECIES	SEX	DATE RECEIVED	HYPOTHETICAL BIRTH DATE	ESTIMATED AGE IN YEARS JAN., 1951
Bedford, Va.	M'Bam	G. gorilla	M	Oct., 1950	June, 1947	3–4
[1]Noell's Ark Gorilla Show (R. Noell)	Golly Gal	"	F	June, 1950	Oct., 1949	1–2
Brookfield, Ill.	Baby	"	M	Apr., 1951	Sept., 1949	1–2
Chicago Zool. Park. (Robert Bean)	Sappho	"	F	Apr., 1951	Oct., 1948	2–3
Chicago, Ill.	Bushman[2]	"	M	Aug., 1930	Jan., 1928	23
Lincoln Park Zool. Gardens.	Sinbad	"	M	Oct., 1948	Feb., 1948	2–3
	Rajah	"	M	Oct., 1948	May, 1947	3–4
(R. Marlin Perkins)	Irving Young	"	M	Oct., 1948	Jan., 1947	4
	Lotus	"	F	Oct., 1948	Apr., 1946	4–5
Cincinnati, Ohio.	Big Boy	"	M	Aug., 1949	Mar., 1946	4–5
Zool. Society of Cincinnati. (J. F. Heusser)	Tiny	"	M	Apr., 1951	Sept., 1950	½
Cleveland, Ohio.	Eseka	"	M	June, 1950	Jan., 1948	3
Zool. Park.	Yokadouma	"	F	June, 1950	May, 1946	4–5
(F. A. Reynolds)	Bengbis[3]	"	F	June, 1950	Feb., 1950	1
Colorado Springs, Col. Cheyenne Mt. Museum and Zool. Society. (R. V. Menary)	Mr. Bud	"	M	Sept., 1949	Nov., 1947	3
	Gorgeous	"	F	June, 1950	Jan., 1949	2
Columbus, Ohio.	The Baron	"(?)	M	Jan., 1951	Oct., 1946	4–5
Zool. Society.	Christina	"(?)	F	Jan., 1951	Aug., 1949	1–2
(Earl F. Davis)	Christopher	"(?)	M	Jan., 1951	Sept., 1949	1–2
Goulds, Florida. "Monkey Jungle" (Joseph DuMond)	Bulu	"	M	June, 1950	Dec., 1946	4
Lintz, Gertrude, Brooklyn, N. Y.	Zulu	"	M	June, 1951	Mar., 1951	Unborn
Milwaukee, Wisc.	Sambo	"	M	Oct., 1950	June, 1949	1–2
Zool. Gardens. (George Speidel)	Samson	"	M	Oct., 1950	Sept., 1949	1–2
New York, N. Y.	Carolyn	"	F	July, 1943	Jan., 1940	11
Central Park Zoo. (John Galm)	Joanne	"	F	July, 1943	Jan., 1940	11
New York, N. Y.	Oka	"	F	Sept., 1941	Apr., 1940	10–11
Zool. Society.	Makoko[4]	"	M	Sept., 1941	Sept., 1939	11–12
(Fairfield Osborn)	Sumaili	G. beringei	F	June, 1949	Nov., 1947	3–4
	Mambo	G. gorilla	M	May, 1951	Nov., 1949	1–2

TABLE 1.—*Continued*

LOCATION	NAME	SPECIES	SEX	DATE RECEIVED	HYPOTHETICAL BIRTH DATE	ESTIMATED AGE IN YEARS JAN., 1951
Philadelphia, Pa.	Bamboo	G. gorilla	M	Aug., 1927	Aug., 1926	25
Zool. Garden.	Massa	"	M	Dec., 1935	Jan., 1931	20
(F. M. Shelly)						
Ringling Bros.,	Toto[5]	"	F	Mar., 1941	Jan., 1932	19
Barnum &	Mlle. Toto	"	F	Nov., 1949	Aug., 1949	1–2
Bailey Shows.	Gargantua II	"	M	Nov., 1949	Sept., 1948	2–3
(John and Henry Ringling North)						
St. Louis, Mo.	Phil	"	M	Sept., 1941	Sept., 1939	11–12
Zool. Park.	Bobo	"	M	Oct., 1948	Sept., 1947	3–4
(G. P. Vierheller)	Bobby	"	F	Jan., 1950	Sept., 1947	3–4
San Antonio, Texas.	Juba	"	M	June. 1950	Oct., 1948	2–3
Zool. Society.	Mimo	"	F	June, 1950	Oct., 1948	2–3
(Fred Stark)						
San Diego, Calif.	Albert	"	M	Aug., 1949	Feb., 1949	2
Zool. Society.	Bouba	"	F	Aug., 1949	Oct., 1948	2–3
(Belle J. Benchley)	Bata	"	F	Aug., 1949	Nov., 1948	2–3
Yale University;	Farquhar	"	F	June, 1951	Jan., 1948	3
New Haven,	Robert	"	M	June, 1951	Jan., 1950	1
Conn.						
(John F. Fulton)						

[1] Golly Gal died May, 1951. [2] Bushman died January, 1951. [3] Bengbis died April, 1951. [4] Makoko died May, 1951. [5] Received from Mrs. E. Kenneth Hoyt, who had reared her from infancy.

Of the 44 specimens listed in Table 1, four died during the period of census-taking. Among the survivors males preponderate 23 to 17, and juveniles (under five years), 33 to 7.

As I stated at the outset, this is a plea for gorilla study. Heretofore almost no scientific use has been made of imported specimens during their life in captivity, and at death the bodies rarely have been properly preserved and made available for morphological study. Sometimes skull, skeleton, or skin has been presented to a museum, or in case of fine adult specimens the skin has been mounted for exhibition. For decades there has been wastage of potentially valuable materials and of opportunities for research, which reflects unfavorably on American biologists and is, I submit, inexcusable.

Primarily responsible for this regrettable history of default and neglect is the fact that almost all specimens are purchased for exhibit by zoos or shows. Only very exceptionally has one been owned by an individual or institution whose main concern is research. Evidently we biologists, even with specimens at hand,

have lacked sufficient initiative and compelling interest to discover and develop opportunities for gorilla study. This is our responsibility and our special business. The responsibility is the more weighty because never in human history have essential conditions been so favorable for the study of gorilla nature, and the effective use of the animals as experimental subjects, as in America today.

A few suggestions taken from my long experience in trying to promote the effective use of anthropoid apes may be pardoned. As I see it, the primary need is mutual understanding and the establishment of co-operative relations between owners of gorillas (mostly executives of zoos or shows) and biological investigators. There must be mutual respect and consideration for one another's obligations and interests, since neither zoo nor road show is as favorable an environment for research as is the university.

Granted the will in owner and scientist to arrange for research in zoo or circus quarters, such lines of work as the following may prove feasible. Naturalistic studies of daily life; of habits and instincts and their variation, modification, and interrelations; of nutritional needs and their satisfaction; of individual traits, or peculiarities, in structure and function. Such studies may be conducted without any considerable interference with the exhibition of the subjects. It may even be to the great advantage of the animals because of the diversion, exercise, and novel situations provided by the scientist. Thus, incidentally, the investigator may become an important asset instead of a nuisance in the zoo or circus set-up.

Diary records of growth and development (weight and other physical measurements, dentition, appearance of inborn patterns of action, and unusual happenings) may be kept to advantage by the caretaker or keeper. Even such an approach to rigorous research is worthwhile because we know with certainty so surprisingly little about gorilla life.

And always, we students of function should hold ourselves ready and eager for the rare and unpredictable opportunity such as, for instance, once came to me when the hunter, Ben Burbridge, brought home with him a fine four-year-old female mountain gorilla which he had captured in the Belgian Congo. Through his generosity, that of Yale University, and John Ringling, who had purchased "Congo" for the Circus, I was enabled to study her intensively for some weeks during three successive winters in Florida (Yerkes, 1927–28). I might be doing so still if she had lived. She now would be about 28 years old.

Physiological studies of requirements for normal growth, of sexual and reproductive processes, of characteristics of organ functions, etc. now are practicable in several American zoological gardens which employ veterinarians, medical consultants, pathologists, or other trained specialists, and which have laboratories or hospital buildings. In these favorably circumstanced organizations, breeding experiments may at any time become feasible. A few zoos and Ringling Brothers Circus now have on hand sexually mature gorillas, although none has a mated pair. When this happens the advice of an experienced research biologist may prove essential and invaluable. Studies of pathological conditions, diseases, and responses to treatment always are desirable, and here again the usual scientific manpower and other resources of the typical zoo are likely to require supplementation.

It was my privilege in the winter of 1949–1950 to spend several weeks observing three baby gorillas in the Hospital-Laboratory Building of the San Diego Zoo. The facilities for what I wished to do were admirable, and the co-operation of the Director, Mrs. Belle J. Benchley, and her staff was perfect. I cite this as an example of what the scientist may hope sometimes to find if he seeks research opportunity in a zoological garden.

Obviously it is to the advantage of all parties to increase the usefulness of captive gorillas by combining, so far as is practicable, exhibition for educational purposes and biological research. So much, then, for possible uses during the lifetime of a captive. What should happen after its death?

Disposal of the body should not be left to chance or emergency decision. With foresight the interested anatomist or anthropologist should consult with the owner and try to arrange in advance of the animal's death for mutually profitable handling and disposal of the cadaver. Appropriate and immediate preservation, according to suitable directions, and prompt transfer should be agreed upon and assured. "Of course!," exclaims the reader. Why do I dwell on the obvious? Because wastage of the bodies of anthropoid apes in this country has greatly exceeded scientific use. Many, perhaps most, are literally thrown away because the owner does not know what else to do.

There is yet another major excuse for this plea in favor of the scientific use of gorillas. The genus has no chance of survival in competition with man. I hazard also the prophecy that unless preserved by human effort, it will disappear from the earth within a century. I have purposely referred to our wastage of gorillas as inexcusable. Equally so, as I view it, is our failure to create and profitably develop opportunities for the scientific utilization of these great apes while yet they exist in Nature and are fairly easy to obtain.

In support of my pessimistic prediction as to their survival in Nature I offer these facts and surmises. Of the mountain species, *G. beringei*, only a few hundred are thought by competent authorities (Akeley, 1923,1929) to exist, protected by the relative inaccessibility of their habitat and by the Belgian Government. The effectiveness of the latter is attested by the fact that there is only one example of this species in America today—"Somaili," at the New York Zoological Park. Although the species seemingly is not being endangered by human competition or by hunters and collectors, it may be dying out because of slow reproduction and competition with other organisms. This surmise I base on the small population. *G. beringei* appears to be losing the struggle for existence. I hope I am mistaken.

Races of lowland gorillas belonging in the species *G. gorilla* are much more widely distributed than is the mountain species, but unlike the latter they are now in active competition with man for food and in conflict with recent settlers, natives, and foreign hunters and collectors. It is their misfortune also to have become articles of commerce in a highly commercial era. At this moment there are thousands of them in West Equatorial Africa, but the slaughter of adults and the capture of their young is unprecedented. As the agricultural development and exploitation of the continent proceed under the pressure of man's uncontrolled

fertility, the habitat of *G. gorilla* will become more restricted and less safe. Inevitably the population will diminish.

I am fearful that the genus *Gorilla* will not long survive unless intelligently and determinedly protected in a suitable natural habitat area, or bred successfully, as never heretofore, in captivity. While there is yet time and inviting opportunity, we biologists should take determined action to promote gorilla study and to preserve the genus, if not in its native African habitat, then in one or more wisely located breeding colonies.

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School of Medicine, Yale University, New Haven, Connecticut. *Received June 20, 1951.*

NOTES ON A POPULATION OF THE STRIPED GROUND SQUIRREL (*CITELLUS TRIDECEMLINEATUS*) IN AN ABANDONED FIELD IN SOUTHEASTERN MICHIGAN

By Francis C. Evans

One of the paradoxes of natural history is the fact that the most common species are often the least known. What is rare is eagerly sought after, but what lies at our doorstep is ignored. This latter fate seems to have befallen the striped ground squirrel, *Citellus tridecemlineatus*, a wide-spread, frequently abundant, and easily recognized rodent. Although it has been used extensively as a laboratory animal for investigating the physiological aspects of hibernation and reproduction, we know little more than the bare outlines of its life history and ecology. The principal accounts of its habits are those of Vernon Bailey (1893) and G. E. Johnson (1917). In the past thirty years there have been few ecological references beyond some scattered notes on extension of range and on its local role as predator or prey. No careful population study of this species has yet been made.

The past half-century has seen considerable expansion in the range of this spermophile. Its northward extensions in Michigan and Wisconsin and its eastward extension in Ohio have apparently followed the clearing of the land. Although in the course of these movements it seems to have invaded open woodland to some extent, it is primarily an inhabitant of grassland, evidently preferring dry or well-drained situations. Weaver and Flory (1934) reported that over-grazing causes an increase in the striped ground squirrel population, but Phillips (1936) observed a marked reduction of burrow density in heavily over-grazed fields as compared with normally grazed or moderately over-grazed conditions. Linduska (1950) finds that these squirrels tend to avoid cropland entirely but "establish themselves rather rapidly in areas retired from cultivation."

Citellus tridecemlineatus is not generally considered a serious economic pest, although it may cause local damage to garden crops if present in large numbers. Insects such as grasshoppers and caterpillars are said to form a considerable portion of its diet, and in this respect it may be more beneficial than harmful. Quite apart from its economic status, however, its continued extension of range and its tendency to enter habitats created by human disturbance call for further consideration of its role in the ecological communities of which it is a member.

An opportunity to study a small population of the striped ground squirrel was provided by the initiation, in July, 1948, of a project to investigate the structure and dynamics of a community associated with a 15-acre abandoned field on the University of Michigan's Edwin S. George Reserve near Pinckney, Livingston County, Michigan. A brief description of this field has already been prepared in a preliminary study of its vegetation (Evans & Cain, in press). Situated on a glacial outwash plain at an elevation of 975–1000 feet, its rather sterile soil (a sandy loam belonging to the Fox series) supports a vegetation dominated by two species of grass, *Poa compressa* and *Aristida purpurascens*, with which are

associated approximately sixteen other grasses and about sixty-five species of forbs. In earlier work at the Reserve, Blair (1948) termed this assemblage the "blue-grass field association" to distinguish it from the "blue-grass meadow association" found in somewhat moister situations. The latter, characterized by the dominance of *Poa pratensis*, is found in a dozen small hollows or swales scattered throughout the field. For the past twenty years this land has not been subject to disturbance by man or by domestic stock, and its development has taken the course of a slow successional trend towards oak-hickory woodland, which evidently covered the field prior to clearing and which now borders it on the east and on the west.

From his extended study of the small mammal population of a blue-grass field elsewhere on the Reserve, Blair (1948) concluded that *Citellus tridecemlineatus* was relatively scarce in the area and a minor component of that association. In five years (1938–1942) his July trapping, which was evidently carried on after the young squirrels had emerged from their natal burrows and which I estimate to have involved a total of at least 1500 trap-day units (one trap set for one day = one trap-day), yielded only 8 ground squirrels. Using the livetrap employed by Blair (1941) and an essentially identical trapping procedure, i.e., a grid pattern of spacing, with traps 60 feet apart, and a trapping period of six successive days, I obtained, in 1948 and 1949 on the 15-acre field described above, results of the same order of magnitude. In 2032 trap-days during the month of July, I caught only 12 ground squirrels.

However, the frequency with which these animals were seen and the large number of apparently active burrows suggested a greater population and a more important role in the community than was revealed by the trapping results. In 1950, therefore, a more intensive effort was made to study the ground squirrels of this field, and a variety of trapping procedures was used to test the efficiency of the grid system.

I should like to thank R. DeWitt Ivey for his assistance in making a census of ground squirrel burrow entrances and for carrying on the trapping during July and August, 1950. I am also indebted to J. Speed Rogers, Director of the Edwin S. George Reserve, for making the facilities of the Reserve available for this study. William Prychodko prepared the drawings for publication.

METHODS

Marking.—Squirrels were given individual identification marks by clipping the terminal portion of not more than one toe per foot. The toes of each foot were assigned numbers beginning with the innermost or "thumb," and the sequence of marked toes on the right front, left front, right hind, and left hind foot, respectively, comprised the animal's marking number. Thus, an individual whose first toe of the left hind foot was clipped would receive the number 0001, while an individual whose first toe of the right front foot was clipped would be designated 1000. Since these ground squirrels have four well-developed toes on each forefoot and five on each hind foot, approximately 400 individuals can be marked in this manner without duplication. The digits 6, 7, 8, and 9 do not appear in this system. The method has always seemed to the writer a simpler one than

others of its scope, and somewhat less subject to errors of misreading than systems which include ear-marking.

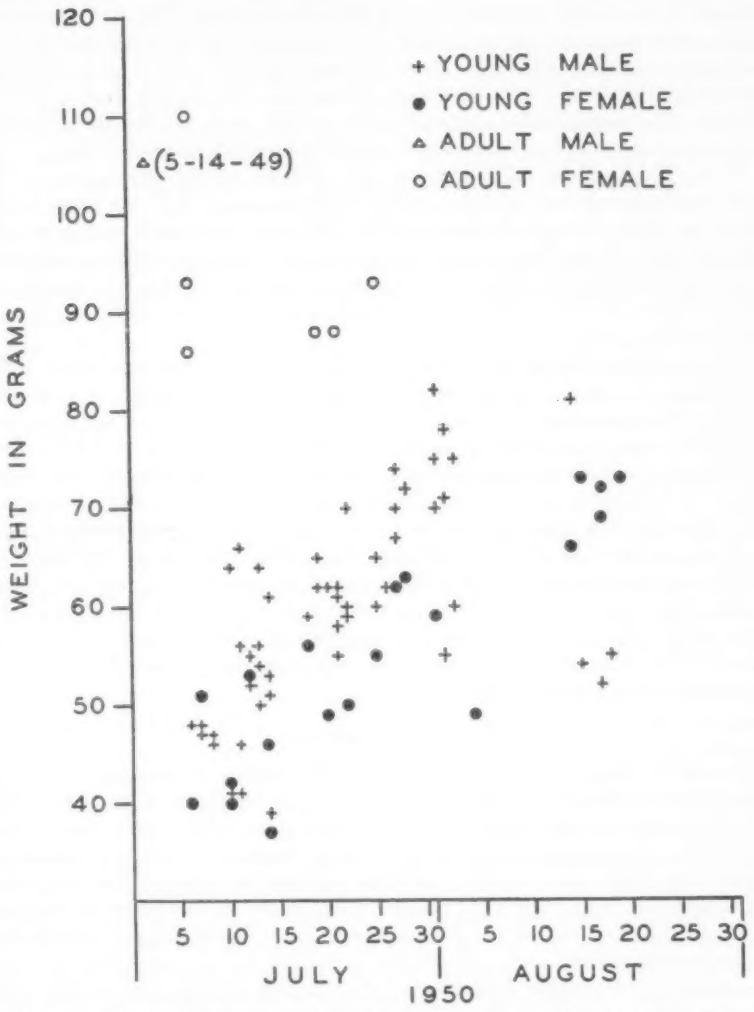

FIG. 1.—Weight records of young and adult ground squirrels caught during 1950 on a 15-acre field, E. S. George Reserve. Weight in grams is plotted against date of capture.

Weighing.—A spring balance, graduated in 10-gram divisions, was used to weigh the squirrels, which were temporarily immobilized in a string bag of $\frac{1}{4}$-inch mesh. Weights had to be read by interpolation and were, therefore, subject

to considerable error apart from the limits of accuracy of the balance. Squirrels were generally weighed the first time they were caught, and at various intervals thereafter, depending upon the frequency of capture. Figure 1 shows a composite picture of the weight records of young and adult animals. The wide scatter of values reflects inaccuracies in reading, daily variations in individual records, and differences between individuals. Nevertheless, juvenile squirrels were evidently distinguishable from adults by weight throughout July and at least a part of August. The young males apparently gain weight more rapidly than juvenile females, as observed for *Citellus beecheyi* by Evans and Holdenried (1943).

Trapping procedures.—The complete grid consisted of 161 traps spaced at 20-yard intervals over the entire field. The traps were covered by tar paper hoods which gave protection from sun and rain, and were baited with both sunflower seeds and rolled oats. They were left out both night and day, and were inspected in the early morning and in the late afternoon and also, during hot weather, in the middle of the day. The entire grid was trapped simultaneously for six successive days.

Three additional trapping procedures were employed in the summer of 1950, as follows: (1) Traps were placed at the base, and in the shade, of numerous juniper (*Juniperus communis* and *J. virginiana*) and hawthorn (*Crataegus crus-galli* and *Crataegus* sp.) bushes which were well distributed throughout the field. One hundred and eleven traps were set for six successive days, plus two additional days. (2) Traps were placed in haphazard fashion in the twelve swales scattered over the field. The dense growth of *Poa pratensis* in these swales offered more concealment than the sparser vegetation of the upland portions of the field. The number of traps placed in these swales totalled 131 and ranged from 3 to 20 per swale. They were run from 6 to 13 successive days each. (3) Traps were placed close to the entrances of burrows which appeared to be in active use or which had been freshly excavated. Eighty-five such traps were run for periods of from six successive days to 25 days each.

TRAPPING RESULTS

Reaction to traps.—Individual squirrels differed widely in their trap reactions. Some of this difference in behavior is shown by the frequency of capture. Of the 26 individuals recorded, eight were caught only once (one of these died in the trap). Two young squirrels, on the other hand, became more or less regular repeaters and were taken 16 times each throughout the summer. The remaining 16 individuals were caught 2–14 times each. Since opportunities for capture were practically unlimited for all the squirrels, these results suggest considerable range in trappability.

Although it is possible that some of the squirrels left the area or died soon after their last capture, it seems more likely that many of them became trap-shy and refused to enter traps in which they had already been caught. This is suggested by the capture data for traps which were placed at burrow entrances. Of the 43 burrow-entrance traps which were entered by squirrels, 40 were not entered more than once by any given individual. On three occasions, squirrels

returned to traps in which they had previously been taken; one of these was caught three times in the same trap, and the other two twice. After the first capture in a given trap, a squirrel apparently tended to avoid that trap, and some individuals evidently avoided further capture altogether.

Additional indication of differences in reaction to traps is suggested by the variation in the number of days elapsing between the placement of a trap at an active burrow entrance and the first squirrel capture in that trap. Two of the 43 traps which took squirrels were occupied the same day they were set, whereas four others required 23–25 days to effect a capture. Nineteen traps were open 1–4 days, and 18 traps took 6–17 days, before the first capture was made. The wide scatter in these records does not indicate any general tendency to enter traps readily or otherwise, but it suggests that some squirrels remained suspicious of traps for many days before they would go inside. One juvenile male, almost certainly a member of this population and not an immigrant, eluded capture until October 3.

It is quite possible that other kinds of traps and/or bait would be more successful or would establish a different pattern of trap behavior. However, the differences in trap reaction noted above indicate some of the limitations of trapping as a technique in studying ground squirrel populations in particular and animal populations in general. Without some knowledge of the reaction of a given population to trapping, the reliability of population estimates, such as the "Lincoln index," which are based on trapping, is open to question.

Some of the squirrels also displayed a marked behavior reaction following release from a trap. These individuals refused to enter nearby burrows and, if approached, would steal off through the grass rather than take shelter in a hole. This is quite different from the behavior of some other small mammals such as *Peromyscus leucopus* or *P. maniculatus* which will usually attempt to find a burrow and disappear down it as rapidly as possible.

Relative effectiveness of different trapping techniques.—The four trapping procedures employed during the summer of 1950 can be evaluated for their relative effectiveness in capturing squirrels. The grid trapping, which was done in June, before the young had appeared above ground, required an average of 249 trap-days per capture: a total of 996 trap-days brought only 4 captures (1 individual). Trapping under bushes was not done until August, by which time mortality, especially among the juveniles, may have caused some reduction in the population; 888 trap-days of bush trapping yielded 23 captures (6 individuals), for an average of 38.6 trap-days per capture. The swales were trapped in July, after the young had become active, and 1422 trap-days in these area resulted in 40 captures (8 individuals), an average of 35.6 trap-days per capture. Burrow trapping, also done in July, averaged 22 trap-days per capture: 1322 trap-days brought 60 captures (22 individuals). Discrepancies in the time of trapping make strict comparison impossible, and the differences among the trapping figures may not be statistically significant, since great variation is common to such data. Nevertheless, the burrow trapping seemed to be very much the most effective, and the grid trapping proved inferior to any of the other procedures. This is what

would naturally be expected, for the catch should be greater when traps are set in suitable places than when they are arranged in some regular manner irrespective of suitability. One of the primary purposes of grid placement is to eliminate the influence of trap position in the comparison of data for two or more trapping periods. Regular spacing of traps is also more efficient in that a given number of traps can be set out and tended more rapidly than when they are arranged in random or haphazard fashion. If, however, grid trapping takes such a small proportion of the population actually present that it provides an inadequate sample for ascertaining the status of the population, its advantages are largely nullified. Some species can apparently be sampled satisfactorily by grid trapping, some cannot, and the investigator must decide what is appropriate in each case. Obviously no single trapping procedure is equally suitable for all species of small mammals in a given area. Recent literature contains a number of suggestions for estimating populations or home ranges based on the regular placement of traps, but the basic question of effectiveness has rarely been considered. Efforts to evaluate the latter for a wide variety of species and situations should be encouraged.

Effect of habitat differences on capture.—Next to the traps placed at burrow entrances, those located in the swales seemed to be the most efficient. The results of the grid trapping furnished a basis for testing the tendency of squirrels to be caught in traps within or close to swales. The 161 grid trap positions were classified according to distance from the nearest swale, as follows: (1) 0–20 yards, 59 traps; (2) 21–60 yards, 60 traps; (3) 61–100 yards, 42 traps. If all of these traps had been equally effective, the number of captures for each distance class should be in proportion to the number of traps in each class. Expected and observed numbers of squirrel captures for the three classes were as follows (the figures include data for both 1949 and 1950, in order to bring class expectations up to 5 for statistical treatment): 0–20 yards, 7.69 expected, 15 observed; 21–60 yards, 7.85 expected, 5 observed; 61–100 yards, 5.48 expected, 1 observed. There is a statistically significant difference between the observed and the expected values ($\chi^2 = 11.633$, d.f. $= 1$, $P < .01$), and the number of ground squirrel captures in traps near swales was considerably greater than would be expected on a chance basis. There is no reason to believe that occupation of the more distant traps by other species had any appreciable effect on the capture of the squirrels. Proximity to a swale, therefore, seems to have been a factor in the distribution of ground squirrel captures.

Home range.—The limited trapping data and observations of activity of the squirrels indicate that, like many other small mammals, they generally occupy a restricted home range. Of the eleven squirrels captured five or more times during 1950, eight were not taken outside of circles with a 50-yard radius and an area of 1.62 acres. The greatest distance between points of capture for any squirrel was 140 yards. Two adult squirrels taken in 1950 were found within the same ranges which they had occupied in 1949. Examples of ground squirrel home range as shown by points of capture are shown in Figure 2. Possible discrepancies between the true home range and the trap-revealed home range, as recently

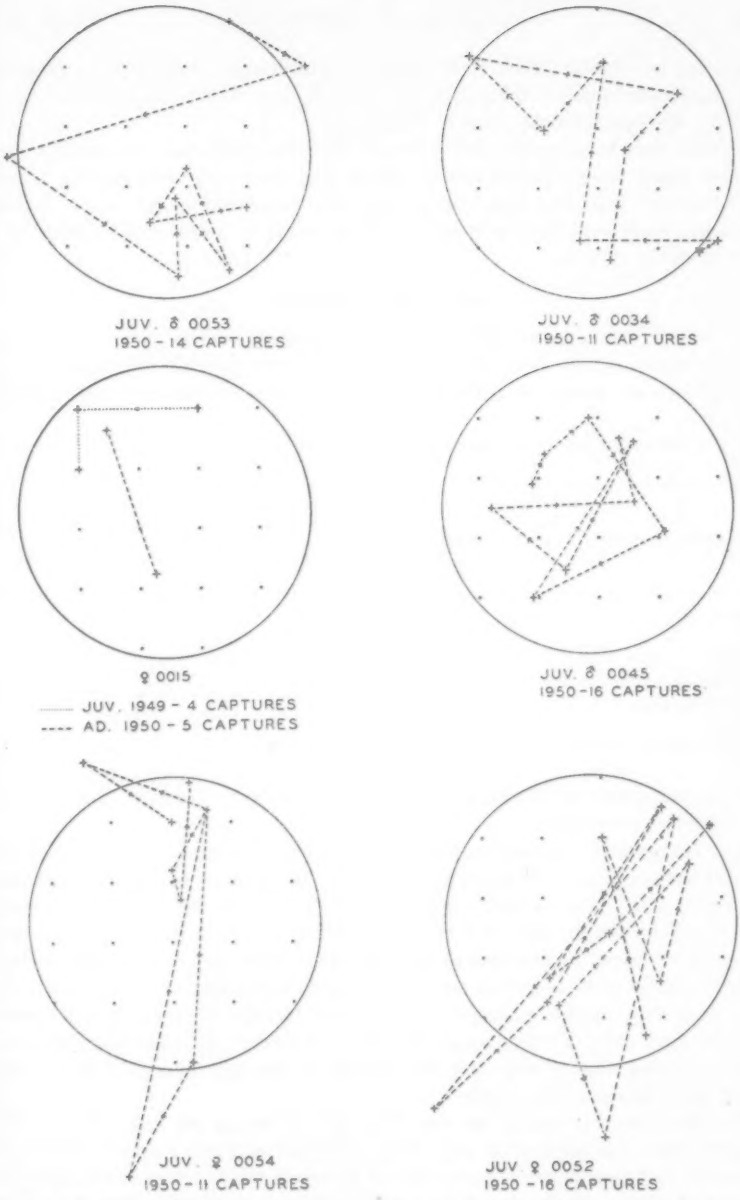

FIG. 2.—Examples of home range of ground squirrels as shown by points of capture on a 15-acre field, E. S. George Reserve. Crosses indicate capture sites, arrows show direction of movement to next capture, and dots indicate grid trap positions. Radius of circle = 50 yards.

discussed by Hayne (1949, 1950), make it inadvisable to attempt to calculate the exact home ranges of these squirrels, but it is believed that the examples given indicate the approximate order of magnitude.

Within their home ranges, the squirrels seemed to limit their wanderings more or less closely to established routes. Many well-worn pathways leading to and from burrow entrances were found and were occasionally seen in use by the squirrels. Such restricted movement may account in part for the failure of a grid trapping system.

POPULATION ESTIMATE

During the summer of 1950, twenty-six ground squirrels were caught one or more times on the field. The numbers of individuals and captures obtained each month are shown in Table 1. The adults taken consisted of three females

TABLE 1.—*Ground squirrels obtained by trapping during 1950 on a 15-acre field, E. S. George Reserve*

MONTH OF APTURE	NUMBER OF SQUIRRELS CAPTURED					
	Adults		Young			Total
	♂	♀	♂	♀	?	
June	0	1^{1}	0	0	0	1^{1}
July	0	3^{7}	13^{85}	7^{15}	0	23^{77}
August	1^{1}	0	5^{20}	3^{21}	1^{1}	10^{43}
October	0	0	1^{5}	0	0	1^{5}
June–Oct. incl.	1^{1}	3^{10}	14^{90}	7^{36}	1^{1}	26^{128}

Superscripts indicate number of captures.

and one male, and the 22 young of the year included seven females, 14 males, and one of undetermined sex.

Any estimate of the total population is difficult because of the wide range of behavior reactions to trapping that have been described above. The unbalanced sex ratio, with twice as many males as females among the juvenile squirrels, might well be simply the result of an incomplete census. Although the evidence of restricted home range seems to indicate rather sedentary habits, the chances of immigration and emigration are not precluded and might serve to explain the capture of an unmarked young male in October and the disappearance of twelve squirrels after July. There is reason to believe, however, that the trapped population included most of the squirrels resident on the area and that there were few if any transient individuals.

The fact that this species has one litter of 7–10 young per year (Burt, 1948) suggests that this population may have consisted of three distinct families of squirrels. This suggestion is borne out by Figure 3, which shows the location of the initial capture of all juvenile squirrels and the areas within which the adults were taken. Definite grouping, apparently of a family nature, is evident, even though every individual cannot be assigned with certainty to a given family

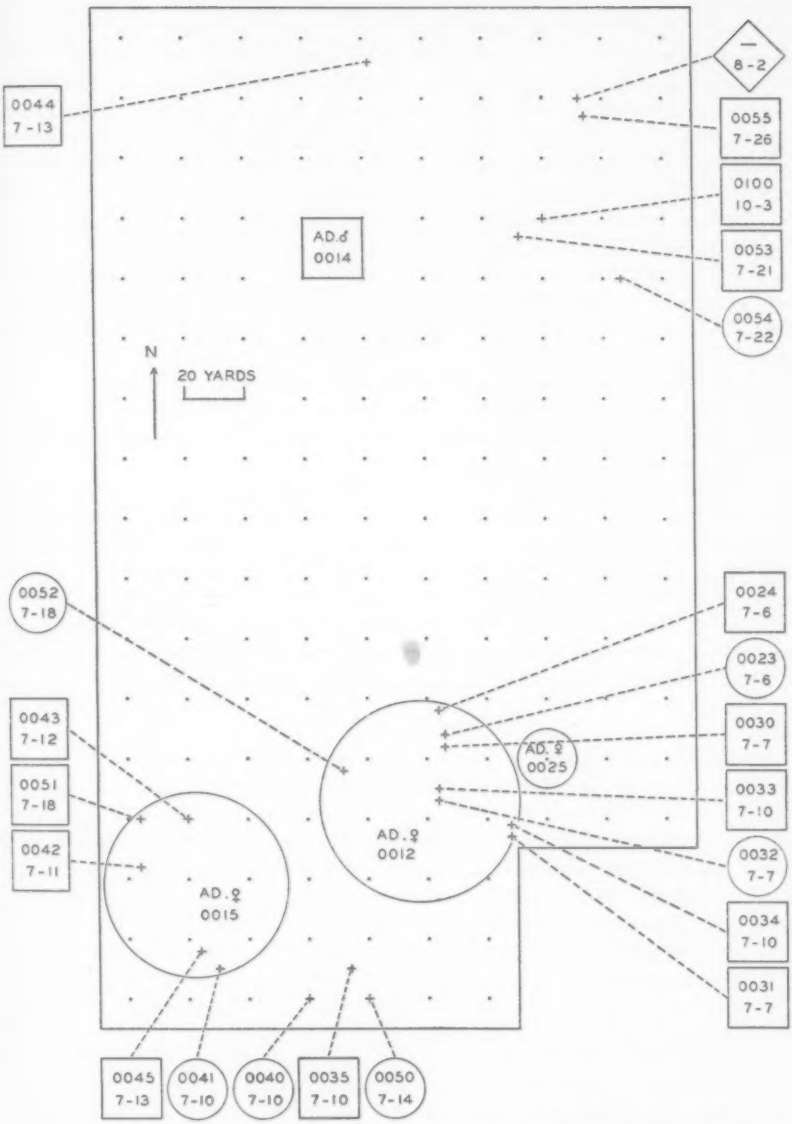

FIG. 3.—Locations (+) of the initial capture of all juvenile ground squirrels taken in 1950 on a 15-acre field, E. S. George Reserve. Circles indicate females, squares indicate males, and the square on the diagonal indicates sex unknown. Boundaries of adult ranges enclose all points of capture. Dates of first captures are indicated in circles and squares.

and the identity of the parents is not entirely clear. Either of the adult females, 0025 or 0012, may be presumed to be the mother of the family occupying the lower right-hand part of the diagram, although the latter adult is favored because her capture record extended from June 13 through July 6 while the former was taken once only (July 6). The mother of the family in the upper part of the figure may have been 0025 or may not have been captured at all. This latter group was not caught as early in the season as the other two, and the time difference is probably responsible for the more widely scattered occurrence of the individuals. The location of the first capture of juvenile male 0100, which was not taken until October 3, strongly suggests that it belonged to this group and was not an immigrant as might otherwise have been supposed. Juvenile female 0052 might be equally logically assigned to either of the two families occupying the lower part of the figure. The composition of the three family groups is presumed to have been as follows: Family One: juvenile males 0024, 0030, 0031, 0033, and 0034, and juvenile females 0023, 0032, and 0052; Family Two: juvenile males 0035, 0042, 0043, 0045, and 0051, and juvenile females 0040, 0041, and 0050; Family Three: juvenile males 0044, 0053, 0055, and 0100, juvenile female 0054, and one unmarked juvenile whose sex is not known. If the latter were assumed to be a female, the sex ratios for these groups are as follows: Family One, 5 males, 3 females; Family Two, 5 males, 3 females; Family Three, 4 males, 2 females. Unequal ratios of this order are not unexpected in small mammal families of this size. Such a phenomenon may help to explain the frequency with which unbalanced sex ratios are encountered in small populations.

It seems likely, therefore, that the 1950 ground squirrel population of this 15-acre field consisted of three families of young and their parents. The total population is estimated to have been comprised of 30–35 individuals.

BURROWING ACTIVITY

In June 1950 a complete count of ground squirrel burrow entrances found on the field revealed 64 burrows which had apparently been constructed in previous years, of which five were evidently again in use, and 47 additional entrances which seemed of more recent origin and were thought to have been made earlier in the current year. Throughout the remainder of the 1950 season, record was kept of each new burrow entrance constructed. In July, at least 45 freshly constructed entrances were discovered, and eleven more were added during August. It is evident that the young squirrels began to make their own burrows soon after their first appearance above ground. Burrow construction dropped off sharply in late summer and ceased entirely by the middle of October; only 14 new entrances were found after the first of September.

Howell (1938) characterizes the striped ground squirrel as "often digging a number of burrows, some of which are shallow and are used for temporary shelter and others of more elaborate construction for more permanent use. These latter . . . are said always to have two entrances." Johnson (1917) found only six burrows with two entrances in 100 which he excavated. Burrow excavation was not attempted during the summer of 1950, since it was desired to avoid all unneces-

sary disturbance. However, close inspection indicated that in many cases there was not more than one entrance to a burrow. It is estimated that the 122 burrow entrances judged to be in active use in 1950 probably represented not less than 100 burrows. The average number of burrows excavated by a squirrel during the year was, therefore, at least three or four.

The distribution of the burrows constructed in 1949 (or earlier) and in 1950 is shown in Figure 4. The general pattern of distribution was similar for both

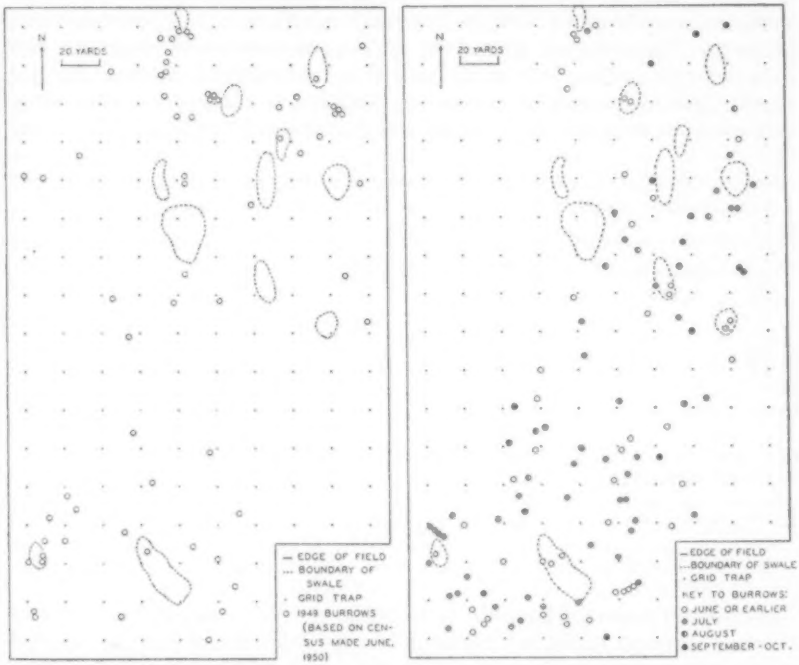

FIG. 4.—Left: distribution of ground squirrel burrow extrances constructed prior to 1950. Right: distribution of ground squirrel burrow entrances constructed in 1950. Fifteen-acre field, E. S. George Reserve.

years and supports the impression of a rather sedentary population. The number of burrows used in 1950 was apparently approximately twice that used in 1949 and suggests a population increase of the same order. The burrow distribution pattern for 1950 indicates some extension of activity over the previous year and conforms quite well to the distribution of families shown in Figure 3.

The distribution of burrows throughout the field was clearly not at random. This was demonstrated by recording the numbers of burrow entrances observed in each of the quadrats into which the field was subdivided by the positions of the grid traps. The observed frequency distribution was then compared with

that which would be expected if the burrows were distributed at random. The data for 1950 has been treated in this manner in Table 2. The value of χ^2 in this comparison (10.859) indicates a statistically significant difference between the observed and the expected distributions. Although the burrows were thus shown to be non-randomly distributed, they were not strongly clumped. In seeking an explanation of the distribution pattern, it seemed possible that this might be correlated with the observation recorded above that squirrels were taken more frequently than expected in traps located in or near swales. Of the 122 burrow entrances actively used in 1950, twelve were located within, or on the boundaries of, swales. The combined area of the swales is estimated to be about one-half acre, having a ratio of 1:29 to the area of the remainder of the field. Had the burrows been distributed at random, we should have expected a corresponding ratio between those located in swales and those located in the rest of the field.

TABLE 2.—*Frequency distribution of ground squirrel burrows in 136 quadrats (approx. 20 x 20 yds. each) on a 15-acre field, E. S. George Reserve, 1950. Mean number of burrows per quadrat = 0.8603*

BURROWS PER QUADRAT	OBSERVED DISTRIBUTION	EXPECTED POISSON DISTRIBUTION	DEVIATION	DEV.²/EXPECT. = χ^2
0	70	57.53	+12.47	2.703
1	37	49.50	−12.50	3.157
2	16	21.29	− 5.29	1.314
3	8			
4	2			
5	2	7.68	+ 5.32	3.685
6	1			
7 or more	0			
Total	136	136.00	0.00	10.859

d.f. = 2; P <.01

The observed ratio was, however, 1:10 instead of 1:29, or about three times as much as expected. Again, the difference between the observed and the expected values is statistically significant ($\chi^2 = 15.003$, d.f. = 1, $P < .01$). It is suggested, therefore, that proximity to a swale may have been a factor in the distribution of burrows. In addition to the greater density of the vegetation in these areas, the noticeably moister condition of the surface soil might facilitate the construction of burrows.

Ground squirrel burrows were used on numerous occasions as refuges by prairie deermice (*Peromyscus maniculatus bairdi*) and probably provided shelter for other small mammals, snakes, and many invertebrates. The results of burrow excavation in bringing fresh soil to the surface and on local drainage may well have had considerable effect upon the physiography of the community. The distribution of burrows indicates a correspondingly widespread influence of the squirrels throughout the field and suggests that under present conditions the species plays a role of some consequence in the dynamics of this community.

SUMMARY

Four adult and 22 juvenile striped ground squirrels were caught 128 times during the summer of 1950 on a 15-acre abandoned field on the University of Michigan's Edwin S. George Reserve in southeastern Michigan. Individual squirrels differed widely in their reactions to traps; in many cases, after the first capture in a given trap, the squirrel tended to avoid that trap. Traps set at burrow entrances proved considerably more efficient than grid trapping, which did not seem to give satisfactory estimates of abundance. The proximity of traps to swales was apparently a factor in the distribution of ground squirrel captures. Of eleven individuals taken five or more times each, eight were not recaptured outside of circles with a 50-yard radius and an area of 1.62 acres, indicating a restricted home range. The total 1950 population of this field was estimated to have consisted of 30–35 individuals, representing three families of young and their parents. Counts of burrows excavated during the summer of 1950 indicated that the average squirrel dug at least three or four burrows during the year. There was a tendency for burrows to be situated in or near swales more frequently than would be expected by chance. The distribution of burrows used during 1950 reflects the family grouping of the population and suggests a role of some consequence for this species in the dynamics of the community.

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ESTIMATION OF VOLE AND MOUSE POPULATIONS ON MT. ISHIZUCHI AND ON THE UPLANDS OF SOUTHERN SHIKOKU

By Ryô Tanaka

I have been employed in the study of populations and home ranges of voles and mice on the uplands in Shikoku; mark-and-release trapping investigations being conducted in 1949 in a *Cryptomeria* afforestation and in a virgin forest on the mountains in Kochi Prefecture, southern Shikoku; in 1950, in a brushy area near the summit of Mt. Ishizuchi, one of the highest mountains in central Shikoku. As a result, I have discovered that this mountain had a far more crowded population of voles than did the uplands in Kochi Prefecture. Knowledge of the faunistic and systematic positions of murine rodents from Shikoku is still rather inadequate, and this is the first synecological study to be made in the province. Therefore, I will explain mainly the investigations on the central mountain and attendantly those on the southern uplands.

This work was aided by a grant from the Scientific Research Expenditure of the Department of Education.

Methods and ecological associations.—Thirty-two small live traps of the single-catch type, made of sheet zinc on roof and sides and of wire netting on floor and bottom, were set on a grid pattern (Fig. 3), being spaced 15 meters apart. Some individuals escaped from some traps because of deficiency in the door apparatus, but the construction of wire netting on the floor was of good service to survival of animals in the trap. The traps were baited with peanuts and sweet potatoes, and each vole was numbered by toe-clipping.

The vegetation on Mt. Ishizuchi consists of three more or less distinct life zones; *Abies* is dominant on the uppermost zone at a height of about 1900 to 1700 meters, below which a *Fagus* zone extends to a height of about 1500 meters, the latter zone gradually shifting into a *Tsuga* zone. The association on the lower area of the *Tsuga* zone and downward is principally formed by *Tsuga*, *Acer*, *Quercus*, and *Carpinus*.

Judged from the results (Table 1) of my preliminary survey on the relative abundance of voles and mice on this mountain, by means of snap-trapping, it has become clear that Smith's red-backed vole (*Clethrionomys smithi*) is decidedly dominant from the uppermost zone downward to heights of 800 to 900 meters; this species occurring nearly exclusively in the *Abies* and *Fagus* zones. (This species name deserves to be re-investigated. For the present I would like to consider it a specialized form among the genus *Clethrionomys*, so this name is adopted here according to Tokuda, 1941.) The Japanese long-tailed field mouse (*Apodemus geisha*) is rarely found above heights of 800 to 900 meters, below which it becomes superior to the vole in occurrence and the Japanese field mouse (*Apodemus speciosus*) begins to appear.

The plot studied lies in the midst of a tract covered with deep and thick growth of bamboo grasses (*Sassa*) at a height of about 1700 meters, corresponding to that of the upper *Fagus* zone. All the animals which visited the live traps during

the period of the study were full grown and young adult or subadult of the red-backed vole. Moreover, it is noticeable that no individual was possessed of evidences of reproductive activity; in the male a small-sized testis was not descended to the scrotum, which was indistinctly developed, and the female kept its vaginal orifice closed. The adult female, therefore, appears to close its vagina at the end of a reproductive period. In the field notes the vole was separated into juvenile, subadult (or young adult), and adult according to size of head and body and pelage coloration, but a reliable determination of sexual maturity was not possible

TABLE 1.—*Number of catches by snap traps (July and November, 1950) on Mt. Ishizuchi*

ALTITUDE (METERS)	VEGETATION ZONE	CLETHRIONOMYS SMITHI	APODEMUS GEISHA	APODEMUS SPECIOSUS	NUMBER OF TRAPS SET
1900–1700	*Abies*	5	1	0	63
1700–1500	*Fagus*	19	2	0	
1500–1300	*Tsuga*	6	2	0	16
1300–900	*Tsuga*	7	1	0	22
900–600		1	3	1	18

TABLE 2.—*Trapping record of the Smith's red-backed vole on Mt. Ishizuchi*

DATE (1950)	NUMBER OF CAPTURES			RATIO OF CATCH PREVIOUSLY MARKED (y)	TOTAL NUMBER PREVIOUSLY MARKED (x)
	Unmarked	Previously marked	Total (w)		
November 1	5*	0	5	0	0
November 2	5*	2	7	0.29	4
November 3	7*	3	10	0.30	8
November 4	5	7	12	0.58	14
November 5	5*	11	16	0.69	19
November 6	5*	12	17	0.71	23
November 7	4	14	18	0.78	27
Total	36		85		

* One animal dead in this group.

for reasons just mentioned. The snap-trapping record shows that there are included one juvenile, one female with distinct mammae, and a few males with rather well-developed scrota in the specimens taken from below a height of 1500 meters. Thus, one can suppose that their reproductive activity might come to rest presumably early in October at latest when they live above this height, because a young born ultimately would have grown to subadult or young adult at the beginning of November.

Population.—The efficiency of trapping in this study is not considered sufficient according to Table 2, because a number of unmarked individuals would have been captured for some days after November 7, if this experiment had been further continued. In this record, it is remarkable that the trapping efficiency is lowest at the beginning of the period and becomes higher and higher toward the

end. Thus, it seems unsatisfactory to estimate the population size only from the total number of unmarked catches in this table.

Hayne (1949) presented a theoretical method for estimating the population size to be reasonably employed even after having marked only part of the animals within the area. He holds that all animals in the population might perhaps be marked only when no replacement of animals occurs during the trapping period and the efficiency of all traps is of great enough intensity, and that when a part of the animals is not apt to enter the traps and marked animals are being replaced by unmarked ones, a completely marked population may be difficult and expensive to attain. His method is a modification of the Lincoln Index method, and his theoretical approach assumes a uniform population size with no replacement of marked animals for the period of the experiment; it further assumes a uniform probability of capture for all animals, marked and unmarked.

The theory of Hayne's method is represented by a straight-line formula $y = \frac{x}{P}$. Herein, after a certain number (x) of animals have been marked and released into the population (P), from which they were trapped, the proportion (y) of the population now marked is $\frac{x}{P}$. P is calculated from the line drawn by the method of least squares through successive samples.

In order to test whether the result of my field work obeys this theory or not, the data are arranged in Table 2 and actual values for x and y are plotted in Figure 1. As will be seen, the set of points never appears likely to fall on a straight line, but does suggest a satisfactory fit to an exponential curve. Notwithstanding, if one dares to apply the Hayne formula, the population size is given as 31.4, far less than the total number of unmarked catches. The reliability of the assumption for an exponential formula can be demonstrated by double logarithmic plots of x and y (Fig. 2).

Here I present a formula, $y = \left(\frac{x}{P}\right)^{\beta}$ instead of $y = \frac{x}{P}$, where β is an index determined by frequency of replacement of marked animals and probability of capture for all animals. If the β value is 1, the formula $y = \frac{x}{P}$ under the two assumptions pointed out by Hayne is consistent, while if it is larger or smaller than 1, y is lesser or greater than $\frac{x}{P}$, respectively, because $\frac{x}{P}$ is always below 1, and the former situation will be chiefly referable to occurrence of significant replacement of marked animals and the latter condition may be mainly reduced to larger probability of capture for marked animals than for unmarked.

We can obtain, by the method of least squares, $y = \left(\frac{x}{38.7}\right)^{0.61}$ as an empirical formula for the theoretical curve, which is exhibited in Fig. 1. Accordingly, the theoretical value of the population is estimated to be 39, and since the β value is less than 1, y should be for the most part larger than $\frac{x}{P}$, the difference being

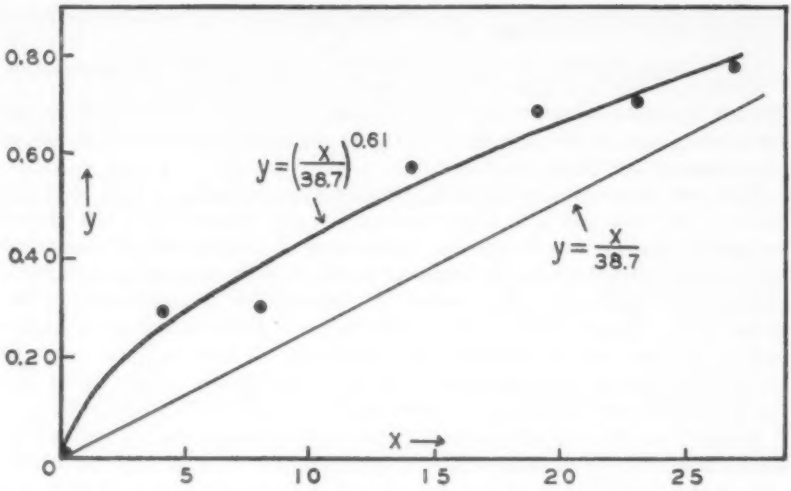

FIG. 1.—Plots of ratio (y) of catch previously marked against total number (x) previously marked, followed by theoretical curve and straight line.

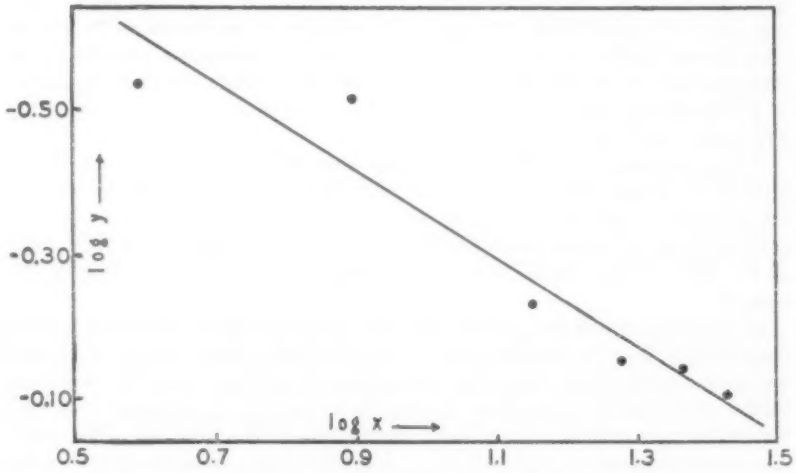

FIG. 2.—Double logarithmic plots of y on x

larger at the beginning of the experiment and gradually lessened with increasing number of marked animals until the whole population is handled at the point ($x = 38.7$, $y = 1$). The interrelation is graphically expressed by the curve ac-

companied by the line $y = \frac{x}{38.7}$. Nevertheless, as a result of χ^2 test as to the fitness of the two formulae, $y = \frac{x}{31.4}$ and $y = \left(\frac{x}{38.7}\right)^{0.61}$ to the samples, it has proved that the null hypothesis is not refuted for both lines, but that χ_0^2 value (0.271) for the former is as large as 20 times that (0.014) for the latter, consequently it will be more reasonable to obey the latter.

Thus, we may well infer from the formula that this vole, at least, becomes liable to enter the trap after it has been marked and released under the present ecological circumstances, so that the replacement of marked voles by unmarked ones scarcely occurs during the trapping period. Whether the value of index β, which I call "mark-and-release index," is characteristic of the species, of the genus, or of a larger group, and to what degree it is influenced by ecological factors, are now almost unsettled, but the survey of these subjects seems to throw much light on the population study. At present it may be only stated that the wood mouse shows just $\beta = 1$ according to the data of Burt (1940:13).

Inasmuch as the trapped quadrat of this study is surrounded by habitats of similar type, we have to admit that some immigrants and transients from outside the area may be contained in the captured animals and that a part of the residents occupying strips outside the quadrat in their normal movements may be taken in the trap lines. What we attempt to obtain as a population size in a territory must be theoretically the number of resident animals on the assumption that they have definite home ranges there at least for a certain period of time. Blair (1941) regarded any animal taken only once as a transient or immigrant to be omitted from the calculation of the population. However, to distinguish transients from residents only by the number of times that they were caught would be impossible of this species at least, because their tendency to enter the trap appears to vary with their individuality.

Taking account of the effect of the trap lines upon the residents outside the quadrat, it is regarded as justifiable to compute the population size by dividing the number of captured animals by the marginal area, a width of one-half the average width of a home range plus the actually trapped area (Dice, 1938, 1941; Burt, 1940). Stickel (1940), however, presents a more reasonable idea in this respect.

As will be described later, the average size of home ranges of males and females together is 0.15 acres, its square root (24 meters) being considered as the average width of a home range. Then, the sum of the trapped area and the additional border area gives 2.4 acres. Thus, the population per acre is computed to be 16.1 by dividing the estimated population above noted by the total area. This population size, obtained in early November, is indicative of a notably higher concentration of the vole; although a few transients and immigrants which occurred during the period studied may be involved in the population. The size surpasses the maximum value (10.9) in late November for *Peromyscus leucopus*, well known for its abundance and its readiness to enter the traps, afforded by Burt (1940), whose conclusions seem to be one of the most reliable knowledges for the present.

The population density of the Bedford's red-backed vole (*Clethrionomys rufocanus bedfordiae*) which was investigated by Ueda (1949) on the lowland of Hokkaido from June to December, 1946, is discovered to be of the highest value (9.4) in June and of the lowest (1.4) in November. The latter value is in marked contrast to that of the Smith's vole in Shikoku.

Home range.—The cruising range of each vole captured two or more times is shown in Figure 3, in which a consecutive series of points of capture are connected by a line beginning with a dot and ending in a sagittal mark. From this,

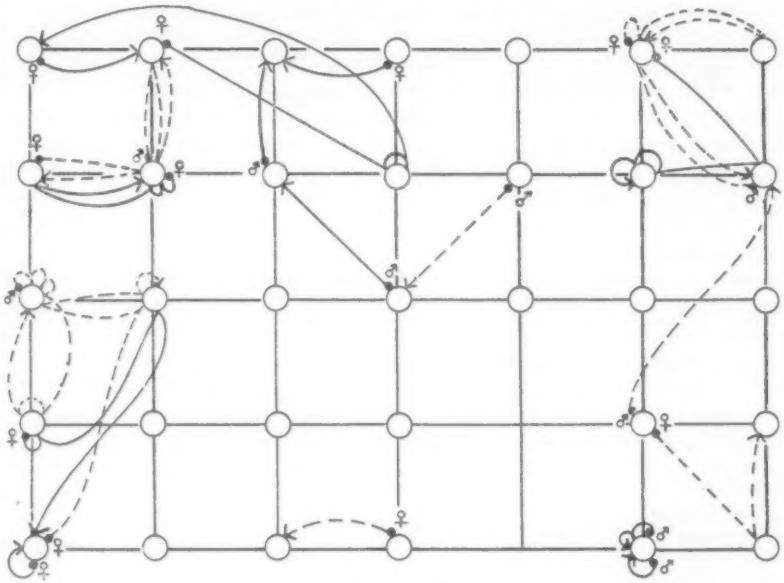

FIG. 3.—Cruising ranges of the Smith's red-backed vole on Mt. Ishizuchi; white circles show site of traps, solid lines for adult, broken lines for young adult or subadult; other explanations in the text.

it is clear that the vole mostly appears within the range of the neighbouring one to three traps, prevailingly restricted to two traps, even when the individuals captured over three times (3 to 7 times) are considered, suggesting that the home range extends not widely around the center of activity.

The calculation of the home range was made, without making a theoretical analysis for estimating because of insufficient material, to include unit squares occupied by traps where one animal was taken, each square covering 0.057 acres surrounded by lines running midway between adjacent traps. If two squares are separated by a trap in which it was not taken, one intervening square is allowed to be contained in the home range. Thus, the size of the home range is in average 0.15 acres (0.1–0.2 acres) for the animals captured three or more times, in which

both sexes, full-grown, young-adult, and subadult are combined. The value is within the range of 0.07–0.23 for the Bedford's vole during the summer offered by Ueda, but generally less than any mean value ever reported of *Peromyscus*.

Hayne (1950) holds, after having studied the home range of a meadow vole, that the calculation of the area covered by its cruising range approaches merely the apparent home range, the determination of which does not seem to reveal a biological characteristic of the normal life history, because the apparent home range obtained in this manner appears to reach a maximum value after a number

TABLE 3.—*Trapping record in a Cryptomeria afforestation in southern Shikoku*

DATE (1949)	APODEMUS GEISHA		APODEMUS SPECIOSUS		TOTAL
	Unmarked	Previously Marked	Unmarked	Previously Marked	
April 8	0	0	1	0	1
April 9	2	0	1	0	3
April 10	3	1	0	0	4
April 11	3	1	0	0	4
April 12	1	1	0	0	2
April 13	1	1	0	0	2
Total	10		2		16

TABLE 4.—*The trapping record in a virgin forest in southern Shikoku*

DATE (1949)	CLETHRIONOMYS SMITHI		APODEMUS SPECIOSUS		TOTAL
	Unmarked	Previously Marked	Unmarked	Previously Marked	
December 23	0	0	0	0	0
December 24	1	0	1	0	2
December 25	2	1	1	0	4
December 26	0	2	0	0	2
December 27	1	1	0	0	2
Total	4		2		10

of captures, but the maximum values are dependent on the distance between the traps. Blair (1942) excluded all individuals that were caught less than ten times from the calculation of the home range size in the study of the deer mouse by reason that such animals seldom ceased to increase their home ranges.

The home range of the Smith's vole here presented, therefore, might be of apparent size, and it might become larger when the calculation is made of animals taken more times than in this work, but it is noteworthy that this vole has grossly agreed with the Bedford's vole in values of the apparent home range, whereas the distance between the traps set was 25 meters for the latter instead of 15 meters for the former.

Voles and mice on the uplands of southern Shikoku.—The field work in a *Cryp-*

tomeria afforestation was performed at a height of 700 to 800 meters on Mt. Hozo in the northeastern uplands of Kochi Prefecture. The method employed was, though less adequate, principally the same as before, namely the traps were set at irregular intervals mainly on new passages or at new burrow exits of the animal through the area covering about 3.6 acres.

From the record (Table 3) one can see that the trapping efficiency is very low and infer that a thin population of mice inhabits the area, which is occupied by only two species of mice, although the population of the wood mice is known to be least in the spring according to Burt (*loc. cit.;* minimum average value 3.1 in mid-May). The dominant species was the long-tailed field mouse, its population being found within a restricted territory with many stumps and logs in the east slope of the area, and two adults, male and female, of the Japanese field mouse occurred solely far apart from the place of the former group.

If the data, though not sufficient, of the long-tailed field mouse are theoretically analysed for estimating the population size, the mark-and-release index appears to approximate 1 in value, giving rise to 8.7 as the theoretical size. Thus, the population per acre is 2.5.

The result of the trapping work carried out in a virgin *Tsuga* forest on the northern upland of Kochi Prefecture is shown in Table 4. The traps were set at intervals of 15 meters in the plot covering about 2.1 acres at a height of 900 meters. The total number of individuals treated during five days was merely ten. The population density obtained directly from the result is only 1.9 for the Smith's vole and 0.9 for the field mouse in late December. This offers distinct evidence to show an extremely thin population of these animals in this region.

Eventually, attention should be paid to the fact that the Smith's red-backed vole is very scarce on the southern upland, whereas it is fairly abundant on the central high mountain in Shikoku.

Summary.—The trapping record of the Smith's red-backed vole in early November at a height of about 1700 meters on Mt. Ishizuchi can be well expressed by an exponential formula $y = \left(\frac{x}{P}\right)^{\beta}$, in which the value of the index β is 0.61 and the theoretical size of the population (P) is 38.7, the former being suggestive of the increase of its liability to enter the trap once it is marked and the latter being indicative of its high concentration (16.1 per acre) on this mountain. The size of the apparent home range was 0.15 acres in average. In spite of such a high density on the central high mountain, the voles and the field mice, especially the former, appear to be notably small in population on the southern uplands in Shikoku.

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Zoological Laboratory, Kochi Women's College, Kochi City, Shikoku, Japan. Received January 10, 1951.

FOOD HABITS OF BALTIMORE, MARYLAND, CATS IN RELATION TO RAT POPULATIONS

BY WILLIAM B. JACKSON

That cats (*Felis domestica*) are important in the control of rats and mice is a well established fact in the minds of many people. Since data are lacking, the object of this project was to secure information on the cat as a rat predator. The observations were made in two residential areas of Baltimore, Maryland, during the summer of 1949. Some of the cats in these areas have returned to the feral state. That some individuals are several generations removed from domesticity is suggested by the fact that one of the most common color patterns is the wild "tiger-stripe." These cats live in deserted basements and other secluded spots, and forage for food in the block. Though many of the cats are semi-domesticated, and are fed limited amounts of table scraps, they, too, probably search for food in the block. Thus it seems that virtually all of the cats may be considered as possible predators on rats (*Rattus norvegicus*).

The alley cats studied live in residential blocks densely populated by Negroes and Caucasians of a low income level. The houses, generally two- or three-story brick structures, are arranged in solid rows facing the street; the back yards are narrow, opening onto an alley. Often board fences, wooden sheds, outdoor toilets, or piles of wood or junk are part of the backyard environment.

The method was to search the yards in sixteen such blocks for cat feces. Scats were usually found in cat scatoria and were taken to the laboratory for examination. Since the blocks were selected without regard for their rat or cat populations, these collections can be considered as random for this part of the city. Another collection of feces was made in a similar row-house area in conjunction with an experiment on the use of rat poison, Compound 42 (M. W. Schein, Pub. Health Rept., 65: 368–72, 1950). Here, six blocks with high rat populations were selected. Collections were made before and directly after poisoning to deter-

mine if a difference occurred in the proportion of scats containing rat remains, for it was thought that rats in advanced stages of poisoning might be more vulnerable to predation.

To identify the various components, the scats were examined under a stereoscopic microscope. Presence of teeth, bones, and hair facilitated accurate identification of the rodents. Thanks are due to Mr. William Stickel of the Patuxent Research Refuge, Laurel, Maryland, for his suggestions on identification of animal remains.

In addition to these two field projects, a laboratory study was conducted with three cats loaned by the Department of Physiology. The cats were fed known amounts of ground horse meat, garbage, rats, and mice. The time required for the passage of food through the digestive tract was determined by examination of the daily collections of scats.

TABLE 1.—*Percentage occurrence of various components in 500 scats from 45 scatoria*

SUBSTANCE	PER CENT OF SCATS	PER CENT OF SCATORIA
Norway Rat (*Rattus norvegicus*)	6.7	29
House Mouse (*Mus musculus*)	0.6	9
Cat hair (*Felis domestica*)	98.0	100
Garbage		
Bird	13.8	55
Fish	63.2	100
Plant fibers, including paper, string, leaves	69.2	96
Crustacea	5.1	24
Insects		
Coleoptera	1.8	16
Orthoptera	4.0	13
Siphonaptera	1.0	7
Formicidae	1.6	7

There was no significant difference in the frequency of occurrence of types of food between the two areas or between the pre- and post-poisoning collections from the second area; therefore, the data have been combined in Table 1 to show the proportion of scats and scatoria containing various substances. The high prevalence of garbage agrees with observations that most cats survive by feeding on garbage or, to a lesser extent, by being fed table scraps. The low prevalence of rodents indicates that they are a small item in the diet for most cats. The almost trace status of the house mouse (*Mus musculus*) can perhaps be explained by the fact that this mammal lives almost entirely inside the houses and seldom ventures outside, whereas the cats generally live outside the inhabited buildings. With the exception of a possible starling (*Sturnus vulgaris*) all the bird remains were those of domestic kinds. Since these remains invariably were a few feathers, claws, tarso-metatarsal and digital scutes, and foot bones, it is concluded that they should be classed as garbage.

Examination of eleven scats from a farm near Baltimore revealed that nine contained either Norway rat or meadow vole (*Microtus pennsylvanicus*) and two

contained large amounts of poultry remains, which probably resulted from kills of barnyard birds.

These data are in general agreement with those of McMurry and Sperry (Jour. Mamm., 22: 185–90, 1941) who found that the diet of feral cats in an Oklahoma residential area contained only 10 per cent rodents, while birds and rodents made up 85 per cent of the diet of feral cats in rural regions. Perhaps the low proportion of rats in the diet of urban cats is due to the general availability of garbage, which reduces the necessity of subsisting on rodents.

Attempts to correlate the number of rats eaten per block with such factors as (1) rat population of the block or dwelling unit, (2) an increasing, decreasing, or stationary rat population, or (3) the number of cats in the block, were unsuccessful. Perhaps when we learn to evaluate the protective nature of the environment we may find correlation between the adequacy of harborage and food and the level of predation.

TABLE 2.—*Frequency of multiple defecations*

NUMBER OF SCATS PER DAY	FREQUENCY	NUMBER OF SCATS
1	20	20
2	14	28
3	7	21
4	1	4
5	6	30
6	2	12
Totals	50	115

The results of the laboratory studies of the cats show that most of the rodent remains (rat or mouse) are passed through the digestive tract within two days after feeding, and that after this time any remains generally will occur in small quantities. A day without defecation or the bulk of a large rat may prolong the total period of passage through the digestive tract.

Often the laboratory cats passed more than one scat each day. (In this paper, any fecal segment over 3 cm. in length is considered as a whole scat. It was not deemed advantageous to analyze the data by taking the volume of the scat into consideration.) Table 2, based on 115 scats defecated over a period of 50 days, shows the frequency of multiple defecations. With this data, an estimation can be made of the number of days represented by the field collections of 500 scats by a simple proportion ($50/115 = x/500$; $x = 218$). Since these laboratory cats were fed a diet somewhat similar to that of the alley cats, and since the scats were similar to those from the field collections, it is a reasonable conclusion that 500 scats represent approximately 220 days in the life of a single cat.

It is interesting to speculate on the effect of cats on a rat population. The blocks had an estimated population of about 1000 weaned rats (census method of Emlen, *et al.* Ecol., 30: 430–42, 1949). For the purpose of calculation let us assume that the rat population of all the blocks represents a single population

of rats, and that one cat defecated the 500 scats over a period of 220 days. The number of rats represented in the scats is estimated, on the basis of laboratory examinations, to be 17. Therefore, this theoretical cat would remove 28 rats in a year ($17/220 = x/365$; $x = 28$ rats).

These 500 scats are believed to come from 45 different cats (number of scatoria = number of cats), about two-thirds of the 70 cats (by actual count) in the area. Hence, during a year, the cats in this area would eat about 1960 ($70 \times 28 = 1960$) rats. This population of 1000 rats contained about 400 adult females, each of which weaned about three litters of eight rats a year, or a total of 9600 rats (D. E. Davis, unpublished data). These speculations indicate that the cats eat about 20 per cent of the rats that must die during the year to maintain a stationary population, or about 18 per cent of the total population. In addition, cats may kill, but not eat, a number of rats during the year. It must not be concluded on the basis of these rough speculations that the rat population would increase by 20 per cent if the cats were absent.

Summary.—To determine the predatory relation of alley cats (*Felis domestica*) to Norway rat (*Rattus norvegicus*) populations in the row-house slum area of Baltimore, 500 cat feces from 45 defecatoria were collected and dissected. Analysis showed that rat remains occur in the scats with a frequency of 6.7 per cent, and that garbage or table scraps constitute the bulk of the food of most cats.

Laboratory observations indicate that about two days are required for the passage of rodent remains through a cat's digestive tract, and that the 500 scats are roughly equivalent to 220 days of defecation for a single cat. It is speculated that the predation of these cats constitutes only about 20 per cent of the annual post-weaning mortality necessary to keep the population stationary.

Contribution from the Vertebrate Ecology Division of The Johns Hopkins University School of Hygiene and Public Health, Baltimore, Maryland. Received August 30, 1950. This study was supported by a grant from the National Institutes of Health, U. S. Public Health Service.

GENERAL NOTES

PEAK POPULATIONS OF *PEROMYSCUS MANICULATUS GRACILIS* IN NORTHERN ONTARIO

During the fall of 1949, Mr. J. L. Grew, Supervisor of trapline management of our Department, returned from a trip through northern Ontario and handed the writer a bottle containing mice which he had collected near Severn River on September 20, 1949. He reported excessive populations of mice and said that they were seen in large numbers around settlements. He also saw a few swimming in the river and mentioned that one boy living in an Indian camp north of Big Trout Lake caught three hundred mice during one morning. The mice were determined to be one *Microtus pennsylvanicus* and six *Peromyscus maniculatus gracilis*.

As this appeared to me to be an interesting case of a peak population of *Peromyscus* so far north, I asked Mr. W. C. Currie, the local Wildlife Management Officer of our Department, to provide me with more information, if possible. He reports the following:

During the fall of 1949 abnormally high numbers of mice were noticed throughout the entire Patricia area (the portion of Ontario adjoining Hudson and James bays). Every Hudson's Bay Post reported mice to be more abundant than for many years.

There were several mice swimming in the rivers, but more were seen floating around dead. The only place where Messrs. Grew and Currie spent any time on a river was on the Severn, about sixty miles from its mouth. However, the same report came from all other parts in the area and trappers stated that they had seen several dead mice floating in lakes and rivers and a few of them around their camps.

During the summer of 1950, trappers in the area north of Pickle Lake up to Hudson Bay reported seeing no mice at all, or in very rare cases one or two.

The species observed were, according to Mr. Currie, thought to be mostly "lemmings" (probably *Clethrionomys* or *Synaptomys*), but there were also deer mice and voles.

The above information indicates possible population peaks of several small rodents during the year 1949, and a subsequent crash. Although such peak populations are known to occur among lemmings and voles, they possibly are not recorded—at least at such a high latitude—in Ontario for the deer mouse.—A DE VOS, *Department of Lands and Forests, Toronto, Ontario. Received February 10, 1951.*

RED FOX FOOD HABITS IN A WILDERNESS AREA

During 1947, the author conducted a food habits study of the red fox (*Vulpes fulva*) on the Huntington Forest, a large experimental area owned by the New York State College of Forestry in the central Adirondacks, as part of a master's thesis. This portion of the Adirondacks is characterized by rough topography and is almost entirely forested, thereby giving the opportunity to study red fox food habits against a somewhat different ecological background than many prior investigations. These have tended to be located in areas of mixed farmland and woodland which are considered more typical range. A total of 400 scats from all periods of the year was collected and analyzed. In addition, an attempt was made to correlate these findings with data on the abundance and availability of fox foods on the area. The author is indebted to the Roosevelt Wildlife Station, New York State College of Forestry, whose studies on this same area over a period of years were invaluable in supplementing his own records. This article summarizes the tentative conclusions that were reached in the study.

Seasonal feeding variations.—It was demonstrated once again that the feeding habits of the red fox are such that it may truly be called an omnivorous animal. Almost every item that could conceivably be ingested was found to be part of the diet of the fox. In spite of its omnivorous character, the mainstay of fox diet throughout the year was mammalian material. Mammalian tissue showed a frequency of almost 100 per cent in the scats during the winter and spring and never dipped lower than 70 per cent even in the height of the mid-

summer fruit season. The composition of this mammalian diet varied with the season. Deer flesh, mostly carrion, was most important in the winter and early spring. This item never dropped out altogether even during the summer. During the lean months of May and June, all other mammalian food items showed a rise in frequency as deer flesh began to decline. In 1947, during this period, the incidence of insectivore remains gradually increased until it assumed first place which had been held by deer flesh up to that time. The insectivores remained in this position through July and continued to be an important food item until the end of the study in September. Mouse remains, slightly more prominent than insectivores in winter and early spring, were surpassed in June by that group. They attained the lead once again in August and did not show any noticeable midsummer drop in frequences of occurrence in the scats. Remains of the white-footed mouse were predominant in the mouse group by a wide margin. Occurrences of both the red-backed vole and the jumping mouse were relatively low and tended to remain at a constant level. The larger mammals such as red squirrel, chipmunk, and snowshoe hare were found with regularity in the scats, but never attained major prominence. Their highest incidences of occurrence were in the winter and early spring period (except chipmunk) with a gradual decline as the summer progressed until September when there was evidence of the beginning of a new rise.

Bird remains were found in the scats at all seasons and tended to remain at a rather constant frequency level of about 10 per cent, although there was a rise in July and August. Some of the remains were positively identified as grouse, but most were classified as "unidentified bird." Therefore, no definite conclusion can be reached as to the degree of predation exerted upon this game bird by the red fox.

The incidence of fruit in the diet showed a sharp rise in July, after a small beginning in June. The peak of consumption was reached in August, when it was the food item with the highest frequency of occurrence. In September it was equal to the consumption of mammalian food material, but was starting to decline. Raspberries and blueberries, which are widespread over the Huntington Forest, furnished the bulk of this fruit diet.

Correlation of abundance and availability with consumption.—The comparisons of abundance and availability of food items with actual consumption in this study proved that the red fox generally eats what is most abundant and readily accessible. This generalization holds rather well when it is applied to individual items in the fox diet, although there are discrepancies that would seem to indicate some degree of preference. Methods of determining abundance and availability varied according to the nature of the food item under consideration. Line transects of an extensive nature were used to sample the production of fleshy fruits while trapping and accumulative observations provided data for estimating abundance and availability of mammals, birds, snakes, and amphibians. Measurements of these items were not quantitative in an absolute sense, but it is believed that they give a fair picture of the relative amounts of the various potential food items that were present in the area.

The consumption of these various food items followed the varying abundance and availability with a satisfactory degree of sensitivity in most instances. Correlations for deer, birds, red squirrel, chipmunk, and the various species of mice were very good in this regard. The high incidence of insectivore consumption was not supported by trapping results, but this was believed to be due to faulty technique of sampling for this group. Dead individuals were encountered on the little-used roads and trails of the Huntington Forest to a greater extent than other small animals. In addition, correspondence with Dr. C. David Fowle of the Royal Ontario Museum of Zoology mentioned a suspected high of insectivores in Ontario in 1947, while Shapiro (Jour. Wild. Mgt., 14: 359–60, 1950) reported a high population near Syracuse, New York, in 1948. This high incidence of insectivores in the scats was surprising in view of the generally accepted idea that they are distasteful to the fox. One may speculate as to whether a high insectivore population combined with a low population of other, more acceptable, prey such as mice upset normal preferences. Among the fruits, sarsaparilla occurred with a frequency in the scat analysis apparently out of proportion to its minor position in the flora of the forest. Bunchberry, while it was common and

widespread over the area, was not taken by the foxes. A preference and an aversion, respectively, would seem to be indicated.

The food habits of the red fox in this wilderness area as shown by this study appear economically neutral. Poultry and livestock are not commonly maintained in this region and so are not subject to fox predation. The principal game bird of the Adirondacks, the ruffed grouse, is preyed upon, but the degree of predation could not be determined by this study. Winter observations indicated that most of the feeding on deer flesh was on carrion and thus symptomatic rather than causative of the unfavorable condition of the Adirondack deer herd.—ROBERT L. SCHUELER, *U. S. Fish and Wildlife Service, 906 Beacon Street, Boston, Mass.* *Received February 6, 1951.*

FOOD OF A CRIPPLED RED FOX

Ordinarily the red fox (*Vulpes fulva*) feeds largely on rabbits and rodents in the winter season. On March 2, 1949, a "peg-leg" red fox which had the right front paw missing was shot by Mr. William Clapp in Portage County, Ohio. Presumably the paw was lost in a trap from which the animal had managed to escape. Thus hampered it was unable to pursue its usual prey. A stomach analysis by W. G. Purgert and the writer revealed that the stomach was completely filled with a mass of timothy grass (*Phleum pratense*) and a few miscellaneous herbs. Survival had depended upon an entirely vegetarian diet. Other red foxes examined that season contained the usual remains of rabbits and rodents with only a small amount of plant materials.—RALPH W. DEXTER, *Kent State University, Kent, Ohio.* *Received February 2, 1951.*

EARTHWORMS IN THE WINTER DIET OF THE OPOSSUM AND RACCOON

The opossum (*Didelphis virginiana*)and raccoon (*Procyon lotor*) are well known for their omnivorous food habits. Earthworms, however, have been reported in their diet but a few times, especially for the winter season. Taube (Jour. Wild. Mgt., 11: 97–103, 1947) found annelids accounted for 8 per cent of stomach contents of autumn- and spring-caught opossums. Hamilton (Ohio Jour. Sci., 36: 131–140, 1936) was the first to report earthworms from stomachs of raccoon and demonstrated the importance of such food during the fall and winter seasons. He found these animals with a frequency of 19.9 per cent and to constitute 8.44 per cent of the contents from 127 raccoon stomachs. Stuewer (Ecol. Monog., 13: 203–257, 1943) ranked earthworms fourth in importance on a year-round basis as indicated by an analysis of 121 scats of the raccoon.

In winter the earthworms are usually deep in the soil, at least below the frost line. In the winters of 1949 and 1950 mild weather prevailed during much of the season in Northeastern Ohio. Of 13 stomachs from the opossum taken by trappers in January, 1950, seven contained earthworms. These constituted 15.3 per cent of the total volume of stomach contents from all 13 examined. The stomach contents of two raccoons captured on January 17 and February 3, 1949, consisted of 20 and 50 per cent earthworms, respectively. Eight stomachs from raccoon trapped in Portage County during the first week of January, 1950, were also analyzed. The weather at the time these animals and the opossums mentioned above were killed was unseasonably warm with an unusual amount of rain which completely thawed the ground. Earthworms had 50 per cent frequency occurrence and constituted 12.6 per cent of the total volume of stomach contents. A raccoon killed during a midwinter thaw on January 19, 1951, by Bernhardt Raithel in Portage County contained two fragments of an earthworm. Apparently these species are able to find earthworms in significant quantity during mild weather of the winter season. The following students assisted in this study: R. T. Hird, D. E. Weckerly, W. N. Byrn, and John Monahan.—RALPH W. DEXTER, *Kent State University, Kent, Ohio.* *Received February 2, 1951.*

THE USE OF THE TAIL BY AN OPOSSUM

The opossum's use of its tail to carry objects was apparently first recorded by Pray (Jour. Mamm., 2: 168–169, 1921) who described and illustrated the method of holding leaves

in the tail, but did not record the manipulations involved in gathering and placing the material.

Recent observations on a young male opossum, *Didelphis v. virginiana*, kept in captivity since September, 1950, in a large outdoor cage at Ithaca, New York, have provided additional information on this use of the tail in carrying nest material.

On numerous occasions, both during the day and in the evening, this animal has been observed gathering dead leaves, feathers, or scraps of newspaper and carrying them with its tail to a nest box. The procedure of gathering and affixing the material in the tail is almost invariably the same. Grasping the object in its mouth, the opossum passes it back under arched body with the aid of its fore feet. The tail is held curved beneath the body, the material pushed into the resultant crook where it is firmly packed by alternate thrusts of the hind feet, and the animal moves off with the objects gripped in the coiled tail. Usually it returns directly to the nest box to deposit its burden, but at times hesitates to feed or drink, retaining its clasp on the leaves or other debris in the meantime.

The individual under observation is somewhat handicapped, since the tail has been reduced through self mutilation to a stub about one-half the original length. Mutilation of the tail is of rather common occurrence among captive opossums.—James N. Layne, *Department of Conservation, Cornell University, Ithaca, New York. Received February 6, 1951.*

LUMP-NOSED BAT IN ARKANSAS

In 1936 (Jour. Mamm., 17: 29–35) Black listed a single known specimen of *Corynorhinus rafinesquei rafinesquei* (Lesson) from Arkansas. This was a skeleton, no. 5645 Univ. Kansas collection, taken at Mulberry, Crawford County, Arkansas, October 1, 1926. This species appears to be sporadic in occurrence throughout its range. It has been reported from Illinois by Necker and Hatfield (Bull. Chicago Acad. Sci., 6: 1941) and by Elder (Jour. Mamm., 26: 433–434, 1945) who obtained a sight record in northeastern Alexander County, Illinois. Elder (personal communication) has also obtained a specimen from Stone County, Missouri, which is just across the Arkansas line in southwestern Missouri. In view of its supposed scarcity in Arkansas, the following additional records of this bat are presented.

The first specimen collected was an adult male (Univ. Arkansas Zoology Department collection, no. M50-6) which was taken on October 15, 1950, from Hewlitt cave, 12 miles west of Fayetteville, Washington County, Arkansas, by the writer in company with Dr. Howard Young and Mr. Barry Walker. This specimen was not in a hibernating condition when collected. On December 4, 1950, the writer and Dr. Young again visited Hewlitt cave and collected another adult male (no. M50-14) in a hibernating state. On January 12, 1951, the writer collected an adult female (no. M51-1) from a cave known as the Devil's Icebox, which is located about 25 miles southwest of Fayetteville, in Devil's Den State Park, Washington County, Arkansas. This specimen was also in a hibernating state when collected. On February 24, 1951, eleven additional specimens of this bat were collected from this same cave (nos. M51-51 to M51-61). Three of these were males while the rest were females. They appeared to be in a state of partial hibernation. All of the males were in full breeding condition with testes descended and the reproductive tracts of the females were enlarged and turgid.

Out of a total of over 15 caves visited, that were within a 25-mile radius of Fayetteville, during a period of over four months, this species was found in only two. From the number of records, it does not appear to be particularly rare in this region of Arkansas, but it is definitely sporadic in its occurrence.

Mr. Colin C. Sanborn of the Chicago Natural History Museum has kindly verified the identification of this species.—John A. Sealander, Jr., *Department of Zoology, University of Arkansas, Fayetteville, Arkansas. Received February 15, 1951.*

CONSUMPTION OF SHRIMP BY THE BOTTLE-NOSED DOLPHIN

Shrimp are among the most abundant marine animals, in terms of species mass, in shallow waters of the Gulf Coast of the United States, and they support a large commercial

fishery, which in some years produces 200,000,000 pounds. Shrimp are eaten by a wide variety of marine organisms. A recent manuscript by an authority on shrimp, Mr. Martin D. Burkenroad, states that they are eaten by practically all organisms that live in, over, or near the sea, including at times even the jellyfish. The writer wishes to record here certain information showing that shrimp are also an article of diet of the bottle-nosed dolphin, *Tursiops truncatus* (Montague), the common "porpoise" of the south Atlantic and Gulf.

In a previous paper (Jour. Mamm., 23: 267–276, 1942) the writer recorded one shrimp among many fishes taken from the stomachs of dolphins in Texas waters and reported fishermen as saying that the dolphins eat shrimp. At that time the late E. A. McIlhenny of Avery Island, Louisiana, got in correspondence with me and gave supporting information with permission to publish it. The recent death of this well-known naturalist and conservationist reminded me that the material has gone unrecorded. Mr. McIlhenny's letter of February 8, 1944, stated as follows:

"In this connection, the following fact may be of interest: For many years it has been the custom of this large plantation to use Porpoise or Dolphin skins for the making of the leather harness used on the mules in plowing the fields. The reason for using porpoise skins was that it contains so much oil that it remains soft and does not harden with the excessive rains we have all during the summer. Each spring, for many years, I would go out into the passes connecting Vermilion Bay with the Gulf, and harpoon porpoises to obtain their skins. On March 12, 1938, I harpooned three large porpoises in Southwest Pass between Marsh Island and the mainland connecting Vermilion Bay and the Gulf. The pass is from 80 to 100 ft. deep, and about three miles long. These porpoises were skinned within one-half hour after being caught, and upon opening them I found from one to two gallons of extra-large shrimp in their stomachs. These shrimp were so fresh that after washing in several waters, they were cooked and used for food. Not one of all the shrimp taken from these porpoises were mangled. They were evidently swallowed whole, and probably swallowed only a few minutes before the porpoises were caught.

"On a number of other occasions I have found shrimp in the stomachs of porpoises."

The writer's paper (*op. cit.*) mentioned the fact that the bottle-nosed dolphin is troublesome to shrimp fishermen because it tears open the trawls to get to the catch. At the time that paper was written it was thought that the animals tore open the nets chiefly for the fish within. It now seems more probable, however, that they will eat both the fish and shrimp taken in the shrimp trawls.

The writer (*op. cit.*) had noted that the bottle-nosed dolphin does not bite or mangle the fish it swallows. Shrimp are much more fragile than fish, but Mr. McIlhenny's observation indicates that they follow the same habit when feeding on shrimp.—G. GUNTER, *Institute of Marine Science, The University of Texas, Port Aransas. Received February 13, 1951.*

A CRANIUM OF *MAMMUTHUS* (*ARCHIDISKODON*) CF. *IMPERATOR* FROM NORTHEASTERN SOUTH DAKOTA

The first proboscidean cranium from South Dakota was collected by the South Dakota School of Mines and Technology Museum of Geology in the Fall of 1949. This specimen was found seven feet below the present ground surface in the Wisconsin Drift six miles north of Mina, Edmunds County, South Dakota, on the O. C. Kienast farm, in the NW ¼ Sec. 13, T. 124 N, R. 66 W, Pembrook Township.

Previous proboscidean remains found in South Dakota have been restricted to mandibles, isolated teeth, tusks, and skeletal fragments. This specimen (SDSM no. 4911) consists of a badly crushed cranium with one tusk, the right third upper molar, and several fragments of vertebrae, ribs, metapodials, and phalanges.

The skull was apparently uncrushed prior to discovery. It was found during the excavation of a stock tank. The bulldozer ran over the skull several times before it was exposed and finally uncovered it by cutting through the top of the cranium and through the center of the tusk. During collection the curvature and size of the entire tusk was determined and plotted. The bone was in excellent condition and most of it was readily prepared by soaking and washing in water.

A point of interest is that the right side of the forehead in the region of the frontoparietal suture has a depressed area 5½ inches in diameter and 1½ inches deep. The bottom of this area is very rugose, being composed of callous bone tissue. It may be postulated that this represents an old and completely healed wound, possibly inflicted by another elephant.

The tusk measured 12 feet 6 inches from the alevolar border to the tip, the diameter of curvature from the center of the tusk at the alveolus to the tip was 71 inches, the diameter of the tusk at the alveolus was 7 inches. The single cheek tooth, the right M^3, has an anteroposterior diameter of 187 mm., the greatest transverse diameter is 97.3 mm. There are fourteen plates with seven plates to 10 cm., three of the loops are contiguous. The enamel is strongly crenulated and the cement on the lateral borders has a maximum thickness of 3 mm.—J. R. MACDONALD, *Museum of Geology, South Dakota School of Mines & Technology, Rapid City, South Dakota. Received January 29, 1951.*

A FEMUR OF A (?) CHALICOTHERE FROM THE PLIOCENE OF UPPER BURMA

The purpose of the present note is to draw attention to an apparently interesting discovery, now more than half a century ago, by Dr. F. Noetling, but almost completely overlooked thus far.

Noetling (1897*a*), paleontologist to the Geological Survey of India, published an article about a slightly injured left femur found by him in a ferruginous conglomeratic layer at Yenangyaung, Upper Burma, Pliocene in age, and identified as "*Hippopotamus irravadicus*, Caut. and Falc." Noetling's paper is illustrated with three views of the bone, ⅓ natural size. A figure of the bone as found in situ is given in a subsequent paper (Noetling, 1897*b*: 241, fig. 3). Apparently since this bone was found in (not too close an) association with certain (?) worked flints, the femur found its way in archaeological literature and completely escaped the attention of vertebrate paleontologists thus far. For the sake of completeness I may list the references to the fossil femur of Upper Burma which I could find: Swinhoe (1902: 323-24), Pascoe (1912: 53), Das Gupta (1923: 14), Mitra (1927: 133), and Hooijer (1950: 36). In the last mentioned paper I took up the question of the true relationships of the bone, stated that it cannot belong to the genus *Hippopotamus* because of its having a third trochanter, and suggested that it may be a perissodactyle femur. The identification of the specimen seems not to have been questioned before; in fact the femur is not mentioned at all in the literature on fossil mammals from Burma (Colbert, 1938, 1943) nor in the more recent archaeological literature on Burma (Movius, 1943, 1944, 1949).

I have now come to the conclusion that it is probable that the femur belonged to a chalicothere. The length (given by Noetling as 600 mm. from the top of the great trochanter to the middle of the distal condyles) indicates that the animal must have been about the size of the Miocene North American *Moropus*, of which a number of femora have been available to me for comparison in the American Museum of Natural History, as well as the one figured in Holland and Peterson (1914, pl. LXX).

After having made comparisons with all sorts of recent and fossil mammals to which the fossil femur from Burma may belong I decided that chalicothere relationships are the most probable, but no femur of an Asiatic chalicothere has ever been described thus far, although we know *Macrotherium salinum* and *Nestoritherium sivalense* from the Chinji-Nagri and the Pinjor zones, respectively, of the Indian Siwaliks (Colbert, 1935), of which the Burma fauna with which the femur under consideration was found is only an eastern extension. *Nestoritherium sinense* occurs in the Middle Pleistocene of southern China (Colbert, 1934: 384), and puzzling *Postschizotherium chardini* Von Koenigswald is from the Pliocene of southeastern Shansi (Yushê), and from the Lower Pleistocene of Nihowan, China (Teilhard de Chardin, 1939). The Mongolian chalicotheres are Eocene through Miocene in age (Colbert, 1934), while Lower Pleistocene molars (Von Koenigswald, 1935; 1939; p. 35; 1940, p. 61, pl. II, fig. 13) indicate the presence of chalicotheres in Java.

Thus, although we certainly need a better specimen to settle the identity of this large mammal, I would not be surprised if chalicotheres turn up some day in the Pliocene of Burma. The associated fauna (*Hipparion antelopinum* and *Aceratherium lydekkeri*) points to Lower Irrawaddies, which now stand as Middle Pliocene (Colbert, 1938: 277) or Upper

Pliocene (Movius, 1944: 37), and during this time some *Nestoritherium* or *Macrotherium* form may very well have lived in Burma. The present find would seem to be the first record of chalicotheres for Burma.

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DIRK ALBERT HOOIJER, *Royal Ontario Museum of Zoology and Paleontology, Toronto, Ontario.* *Received February 9, 1951.*

THE SUBSPECIFIC IDENTITY OF THE BLACK HILLS FLYING SQUIRRELS (*GLAUCOMYS SABRINUS*)

In his revision of northern flying squirrels (*Glaucomys sabrinus*), Howell (N. Amer. Fauna no. 44; 1918) identified two young specimens from the Bear Lodge Mountains of Wyoming as the subspecies *canescens* of northeastern North Dakota and southern Manitoba. Without examining any specimens from there, he also included the Black Hills within the range of *canescens*. Since his revision, I collected 15 specimens of flying squirrels from the Black Hills. I concur with Howell that the Black Hills squirrels are similar to those of the Bear Lodge Mountains, but it seems clear that the name *canescens* does not apply to them. The Bear Lodge and Black Hills specimens are unlike 10 specimens of *canescens* from Grafton, Walsh County, North Dakota. The two series differ to such an extent that the same subspecific name cannot be logically applied to both series. The Bear Lodge and Black Hills flying squirrels closely resemble the three specimens of *bangsi* from Wyoming that Howell examined. They do not compare closely in skull size and shape with three specimens of *bangsi* from Montana, however. The latter are smaller in external and cranial dimensions, in size of auditory bullae, and in length of rostrum than the three specimens from Wyoming and the 11 adult specimens from the Black Hills. These similarities with the Wyoming *bangsi*, and differences from the North Dakota *canescens*, indicate clearly that the Black Hills and Bear Lodge Mountains flying squirrels should be removed from *canescens* and be treated under the name *bangsi*. I assume that the three specimens from Wyoming fall within the range of variation of *bangsi* as indicated by Howell. If they do not, then neither do the Black Hills specimens.

Compared with 10 adult, winter-taken *canescens* from Walsh County, North Dakota, 11 adults in winter pelage from the Black Hills, South Dakota, are distinctly darker dorsally, vinaceous rather than cinnamon; the cheeks are darker gray; the muzzle, forehead, and supraorbital areas have a strong buffy wash not seen in *canescens*. The hairs of the underparts are slate gray proximally and cinnamon distally, while in *canescens* they are white distally and narrowly gray basally. The tail is more dusky and less reddish dorsally and darker ventrally than is *canescens*. The head and body length averages 10 mm. greater in the Black Hills specimens, and cranial length also averages slightly greater. The greatest difference in the skulls, however, is in the length of the rostrum (see length of nasals below). In this character, the probability that the nasals of the Black Hills specimens are longer than those of *canescens* is slightly more than 99 per cent as ascertained by the Student-Fisher *t* test. The skulls of the Black Hills squirrels also have greater means than those of *canescens* in zygomatic breadth, breadth of brain case, interorbital breadth, and breadth of rostrum. The mean depth of the cranium, however, is smaller than that of *canescens*. In the ratio of the depth to the breadth of the brain case, the *canescens* average greater. In general, the Black Hills skulls can be distinguished from those of *canescens* by greater size and longer rostrum.

Five specimens *of bangsi* from Wyoming were obtained from the U. S. Fish and Wildlife Service Collection. Three of these are complete with skin and skull taken in the summer; the other two were winter specimens with skin only. There is little difference in the summer and winter pelages between the Black Hills and Wyoming specimens. In those from Wyoming, the upper parts, underparts, and tail are buffy-cinnamon in the summer. In the winter, they are more vinaceous dorsally and ventrally. The tail in winter is blackish about the edges. In all external respects, the Black Hills flying squirrels resemble the specimens of *bangsi* from Wyoming. The skulls of the Black Hills specimens resemble the three of *bangsi* from Wyoming; those of *bangsi* are slightly larger (see measurements below).

The three specimens of *bangsi* from Montana are also similar to the *bangsi* from Wyoming and to the Black Hills specimens in pelage color. The skulls of the Montana squirrels, however, are considerably smaller, with a shorter rostrum than either the Black Hills or Wyoming specimens. This discrepancy within the subspecies of *bangsi* deserves further investigation when additional specimens are available.

Measurements.—The following measurements were taken as described by Howell in his

revision. The age of the specimens was ascertained by the amount of wear on PM^4 and M^3. Young adults show little or no wear of these teeth, while in the old adults there is considerable wear on PM^4 and much leveling of the contours on M^3.

Average and extremes of four old adults from Walsh Co., N. D.: skull length, 39.6 (38.9–40.6); zygomatic breadth, 24.3 (23.7–24.8); breadth of brain case, 18.4 (18.1–18.7); depth of brain case 18.0 (17.3–18.7); interorbital breadth, 7.3 (6.8–7.9); length of nasals, 11.8 (11.1–12.1); ratio of depth to breadth of brain case, 0.98 (0.96–1.00).

Average and extremes of five young adults from Walsh Co., N. D.: skull length, 39.0 (38.3–39.8); zygomatic breadth, 24.0 (23.4–24.4); breadth of brain case, 18.0 (17.6–18.3); depth of brain case, 18.0 (17.6–18.3); interorbital breadth, 6.9 (6.5–7.4); length of nasals, 11.6 (11.3–12.1); ratio of depth to breadth of brain case, 0.99 (0.96–1.04).

Average and extremes of five old adults from the Black Hills, S. D.: skull length, 40.8 (39.8–41.5); zygomatic breadth, 24.6 (24.2–25.1); breadth of brain case, 19.3 (18.8–19.8); depth of brain case, 17.7 (17.3–18.3); interorbital breadth, 8.0 (7.8–8.2); length of nasals, 12.6 (12.3–12.9); ratio of depth to breadth of brain case, 0.91 (0.88–0.92).

Average and extremes of seven young adults from the Black Hills, S. D.: skull length, 39.8 (38.4–40.5); zygomatic breadth, 23.5 (22.2–24.3); breadth of brain case, 18.7 (18.1–19.1); depth of brain case, 17.5 (16.8–18.2); interorbital breadth, 7.4 (7.2–8.0); length of nasals, 12.2 (11.8–12.7); ratio of depth to breadth of brain case, 0.93 (0.91–0.97).

Average and extremes of three adults (one old adult and two young adults) from Park and Fremont counties, Wyoming: skull length, 41.5 (40.8–42.2); zygomatic breadth, 25.0 (24.7–25.4); breadth of brain case, 18.9 (18.3–19.4); depth of brain case, 18.2 (17.9–18.3); interorbital breadth, 7.9 (7.4–8.3); length of nasals, 12.6 (12.2–12.9); ratio of depth to breadth of brain case, 0.96 (0.94–1.00).

Average and extremes for three adults (two old adults and one young adult) from Ravalli and Meagher counties, Montana: skull length, 39.4 (39.3–39.6); zygomatic breadth, 23.7 (23.6–23.9); breadth of brain case, 18.6 (18.2–19.2); depth of brain case, 17.5 (17.4–17.6); interorbital breadth, 7.4 (6.7–7.8); length of nasals, 11.8 (11.4–12.4); ratio of depth to breadth of brain case, 0.94 (0.92–0.96).

I wish to express my appreciation to Dr. E. T. Hooper for the valuable assistance he has given me in the preparation of this report.—JOHN A. KING, *Laboratory of Vertebrate Biology, University of Michigan, Ann Arbor, Michigan. Received February 15, 1951.*

MAMMALS OF THE CHASE S. OSBORN PRESERVE, SUGAR ISLAND, MICHIGAN

Sugar Island is in the St. Marys River just below Sault Ste. Marie, Michigan. It is fifteen miles long and varies in width from seven miles at the northern end to about two miles at the southern end. The northern end of the island is farmed, but the narrow southern end is almost completely wooded and uninhabited except by summer visitors, who stay mainly on the shore and seldom venture inland except to travel the one county road. The island gets its name from the large amounts of maple sugar and syrup formerly produced there, and, today, sugaring is still an important source of income for the inhabitants.

The late Chase S. Osborn, former Governor of Michigan, presented the University of Michigan with a large tract of land on the southern end of the island. This tract has been consolidated until at present it consists of 3144 acres, and includes rocky shores, open bogs, tamarack bogs, spruce and white cedar bogs, upland maple and hemlock areas, upland pine and aspen areas, and old fields.

During several periods spent on the Preserve, especially in August of 1948 and 1949 and December of 1949, four main types of small mammal habitats have been trapped: 1) mixed upland forest of spruce, balsam, white pine, and paper birch, with an understory of moosewood, mountain maple, and sugar plum; 2) nearly mature bog forest of spruce, balsam, red maple, and black ash; 3) upland rocky hillsides with an open forest of large-toothed aspen, white pine, paper birch, balsam, and spruce; 4) black spruce bog.

Occurrence records for the larger mammals were obtained from Joseph Andrews, Chippewa Indian caretaker of the Preserve, his father, John Andrews, who also furnished the Chippewa dialect names given here, and from Gilbert Nelson, proprietor of Homestead

store. I wish to express here my gratitude to Joe Andrews for his great help as guide and teacher, and to Professor W. F. Ramsdell of the School of Natural Resources of the University of Michigan, and Dr. C. W. Creaser of Wayne University for their aid and suggestions.

Sorex cinereus Kerr. Masked shrew; Ge-bin-quay-quinse.—Several have been taken, most frequently in the damp spruce-balsam-birch forest; also in the cabin woodpile.

Blarina brevicauda kirtlandi Bole and Moulthrop. Short-tailed shrew.—Taken in all habitats trapped, there was a marked increase in their numbers in 1949.

Myotis lucifugus LeConte. Little brown bat; Po-qua-na-ge.—Two were found dead.

Urusus americanus Pallas. Black bear; Muc-qua.—Frequently seen, tracks are common over most of the Preserve.

Mustela frenata and/or **M. erminea.** Long- and Short-tailed weasels; Ching-woose.—Tracks have been noted in the snow at several localities on the Preserve, but no specimens have been collected.

Mephitis mephitis Schreber. Striped skunk; Chi-gog.—Common, especially in the sandy uplands and old fields.

Vulpes fulva Desmarest. Red fox; Wa-a-guish.—Common.

Canis latrans Say. Coyote; Mush-quo-de-ma-ingon.—Common. Tracks have been seen at all localities on the Preserve. They frequently cross and recross the frozen river in the winter.

Lynx canadensis Kerr. Lynx; Be-jew.—None resident on the Preserve, but Andrews saw tracks and sign in the winter of 1949–50.

Marmota monax Linnaeus. Woodchuck; Coq-wi-geesh.—Common in the hardwoods.

Glaucomys sabrinus macrotis Mearns. Northern flying squirrel.— Three have been taken, apparently common.

Tamiasciurus hudsonicus loquax Bangs. Red squirrel; Gid-a-mou.—Common. Their numbers fluctuate greatly—from an amazing density in 1948 and 1949 to an almost complete disappearance in 1950.

Castor canadensis Kuhl. Beaver; A-mik.—An active colony is present in Little Duck Lake. Their cuttings have been seen for a quarter of a mile up the river shore.

Peromyscus maniculatus gracilis LeConte. Deer mouse; Quay-non-wit-wa-wa-go-no-chi.—Very common; taken in all localities trapped.

Clethrionomys gapperi gapperi Vigors. Red-backed vole; Wa-mik-wa-wa-go-no-chi.—Have been taken in a variety of habitats, including upland mixed forest, rocky wooded hillside, and, in winter, in the black spruce bog. Two gravid females, taken on 21 August 1949, had five and six embryos each.

Microtus pennsylvanicus pennsylvanicus Ord. Meadow vole.—Probably common, but only one has been collected.

Ondatra zibethica Linnaeus. Muskrat; Wo-josh.—A few are found in Duck Lake and the river bays.

Rattus norvegicus Berkenhout. Norway rat.—Found around Homestead and the Coast Guard Station. One was taken in the woods nearly a mile north of Homestead in August, 1949.

Zapus hudsonius hudsonius Zimmermann. Meadow jumping mouse; Qua-quash-go-dwa-wa-wa-go-no-chi.—Apparently not common. Two have been taken, one in an alder swamp, and one in tall grass around the beaver dam.

Napaeozapus insignis frutectanus Jackson. Woodland jumping mouse.—Three have been collected, all in cool, damp situations.

Erethizon dorsatum Linnaeus. Porcupine; Gog.—A few are present, According to Mrs. Osborn, there were originally no porcupines on the island; however, Governor Osborn, about fifteen or twenty years ago, imported from Canada a gravid female which escaped after two days in captivity on Duck "Island."

Lepus americanus Erxleben. Snowshoe hare. Wa-a-bos.—Fairly common in 1949. Their tracks have been seen in the snow almost everywhere on the Preserve.

Odocoileus virginianus Boddaert. White-tailed deer; Mo-wash-gish.—Very common.

John Andrews stated that no deer were known on the island until about 50 years ago, which time coincides with the main cutting and burning on the island.

Alces americana Clinton. Moose; Moose.—There is usually at least one moose on the Preserve all the time. A bull and two cows were seen in 1943, one bull in 1948, in November of 1949 a cow and calf were seen at Homestead Store, and a bull and cow were seen by Andrews in September of 1950. Andrews said he had seen two in one morning swim over in fifteen minutes from the Canadian mainland and come ashore just below the University lodge.

Discussion.—Perhaps the most interesting feature of the Osborn Preserve is its strategic location between the Upper Peninsula–Wisconsin region and the Algoma region of Canada. The local mammals may be divided into two groups—those whose ranges encompass the Great Lakes and those whose ranges stop in this region. It is this second group that encounters the Soo region and the St. Marys River as a potential barrier, either to eastward or westward expansion. Of all the mammals now found on Michigan's Upper Peninsula only five (*Urocyon cinereoargenteus, Glaucomys volans, Citellus tridecemlineatus,* and *Sylvilagus floridanus*) do not range eastward to the river. There are two which are apparently stopped eastward at the river—*Sorex arcticus* and *Taxidea taxus*. Snyder (Trans. Royal Canad. Inst. 24:99–165, 1942) has found *Parascalops breweri, Sorex fumeus,* and *Microtus chrotorrhinus* at their most westerly limits just across the St. Marys River in Canada. There are several striking additions to and omissions from the expected mammal fauna of the Preserve. No *Procyon lotor, Tamias striatus, Eutamias minimus,* or *Lynx rufus* have been recorded from the Preserve yet they are found on the adjacent mainland. These omissions agree with those found for Drummond Island by Manville (Jour. Mamm. 31:358–359, 1950). Andrews reports that *Martes americana* and *M. pennanti* as well as *Canis lupus* are rare visitants in the winter or early spring. Thus it appears that the St. Marys River with its islands acts as a filter bridge between southwestern, northwestern, and eastern or Appalachian faunal elements.—William O. Pruitt, Jr., *Museum of Zoology, University of Michigan, Ann Arbor, Michigan.* *Received February 12, 1951.*

REVIEWS

Ognev, S. I Звери СССР и Прилежащих Стран (Звери Восточной Европы и Северной Азии) [The Mammals of Russia (USSR) and Adjacent Countries (The Mammals of Eastern Europe and Northern Asia)]. Moscow-Leningrad: Publ. Acad. Sci. USSR. vol. V, pp. 812, figs. 340, plates 13 + XIII, maps XIII, tables 62. 1947. vol. VI, pp. 588, figs. 260, plates XI, maps XII, tables VII, 1948. vol. VII, pp. 736, figs. 347, plates X, maps XV. 1950. [In Russian].

In spite of the magnitude of the barriers to the flow of knowledge between nations, it will always be of the utmost importance for the scientists of any country to be aware of the recent findings of their colleagues of other nationalities. This should be obvious and certainly is as true for mammalogy as for the other natural sciences. It is for this reason that the excellent volumes by Professor S. I. Ognev on the mammals of Russia should be made more widely known.

This monumental work is entirely objective and authoritative, impartially bringing together all of the information on Russian mammals regardless of the nationality of the authors or the publications concerned. Much of the work of Russian mammalogists which has been poorly known in this country is here assimilated and summarized. But the proportion of the material in these volumes which is original is also very considerable.

The first two volumes of this series were titled The Mammals of Eastern Europe and Northern Asia. The subsequent volumes were titled The Mammals of Russia (USSR) and Adjacent Countries, with the subtitle "The Mammals of Eastern Europe and Northern Asia." The earlier volumes of the series are: vol. I, 1928, Insectivora and Chir-

optera; vol. II, 1931, Carnivora (Ursidae, Canidae, Hyaenidae, Mustelidae); vol. III, 1935, Carnivora (Mustelidae, Felidae, Odobenidae, Otariidae, Phocidae); and vol. IV, 1940, Rodentia (Lagomyidae, Leporidae, Pteromyidae, Sciuridae). The contents of the three more recently appearing volumes will be reviewed here in more detail.

In Volume V the subfamily Marmotinae is continued from volume IV and the genera *Citellus* and *Marmota* and their representatives are discussed. In the same volume considered also are the families Castoridae, Myoxidae, and Spalacidae, along with their representative forms. Included in volume VI is the entire family Dipodidae and part of the family Muridae (genera: *Lemmus, Dicrostonyx, Myopus, Ondatra,* and *Prometheomys,* all in the subfamily Microtinae). The remaining genera of the Microtinae are overed in volume VII, which is devoted entirely to them.

The major taxonomic groups used by Ognev are of interest and frequently differ from those employed by Ellerman (1940, 41, 49) and Simpson (1945). For palearctic *Citellus,* Obolensky's (1927) use of the three subgenera, *Colobotis, Citellus,* and *Urocitellus,* is followed. The Russian members of the family Myoxidae are divided into two subfamilies, the Myoxinae (genera: *Glis, Eliomys, Dyromys, Muscardinus,* and *Myomimus*) and the Seleveninae (genus *Selevinia*). The genera *Spalax* and *Myospalax* are united in the family Spalacidae, each being in a separate subfamily. *Spalax* is divided into two subgenera, *Spalax* and *Microspalax.* The Microtinae are divided into four supergeneric groups, The first of these, Lemmi, is equivalent to the group or tribe, Lemmi or Lemmini, of most authors. The Microti or Microtini of recent authors is divided by Ognev into the three other supergeneric groups: Microti (genera: *Eothenomys, Anteliomys, Hyperacrius, Microtus, Alticola, Arvicola, Neofiber, Orthriomys, Herpetomys, Proedromys,* and *Lagurus*), Fibrini (genera: *Phenacomys, Ondatra, Clethrionomys, Dolomys, Prometheomys, Apistomys, Mimomys, Pliomys, Microtomys*) and Ellobii (genus *Ellobius*). In the genus *Microtus* are included nine subgenera: *Pedomys, Neodon, Pitymys, Micrurus, Microtus, Stenocranius, Phaiomys, Blanfordimys,* and *Chionomys.* In the genus *Alticola* are placed the subgenera: *Alticola, Aschizomys,* and *Platycranius.*

The classifications of palearctic and nearctic mammals are closely dependent upon each other, due to the faunal similarity across the Bering Strait region. In this regard it is worthwhile to briefly note some of the palearctic taxonomic considerations which will affect the classification of North American mammals. Ognev (V:185) as well as others (Heptner, 1939, 184; Argyropulo, 1939, 92) have found the susliks or ground-squirrels of the *Citellus parryi-eversmanni* group to be conspecific. The North American forms involved are *Citellus parryi* with its subspecies and the two species *C. kodiacensis* and *C. osgoodi.* At the time of Heptner's and Argyropulo's works, the name *C. parryi* Richardson (1827) was applied to the group since it antedates *C. eversmanni* Brandt (1841). But Ognev has found that the name *Citellus undulatus* Pallas (1778) has been overlooked and should now be considered as the correct species name for the group. An interesting discussion of the related species *Marmota camtschatica* and *M. caligata* is found in volume V, pages 302, 327–328. The relationship between *Castor fiber* and *Castor canadensis* is considered as well (V:348–353). From a comparison of specimens of *Lemmus obensis chyrsogaster* and *L. alascensis,* Ognev believes that these forms have the same species relationship (VI:470). He furthermore emphasizes the need for the future comparison of *alascensis* with the subspecies *chrysogaster, flavescens,* and *paulus.* The need for a complete revision of the palearctic and nearctic collared lemmings (*Dicrostonyx*) is also stressed (VI:508). In a long and detailed discussion, Ognev demonstrates that the name *Microtus ratticeps* Keyserl. et Blasius (1841) more accurately applies to the group previously known as *Microtus oeconomus* Pallas (1778), since Pallas' earlier descriptions are vague and were probably based upon a mixture of specimens of different species (VII:281–282). If the North American members of the *operarius* group are considered as being conspecific with the members of the former *oeconomus* group (Zimmermann, 1942; Rausch, 1950), then these should now be treated as forms of *Microtus ratticeps.*

The great wealth of material presented in these volumes on the Russian rodents is detailed and concerns most phases of their biology. It is only possible to briefly mention

a few of the types of information provided. For all of the taxonomic units, references are cited for the earlier descriptions and names. Present also are keys based upon a number of anatomical differences useful for distinguishing the various groups, from subfamilies down to species. For each genus there is a description of the characteristic features and brief summary of the worldwide distribution. For the species there are preliminary paragraphs devoted to listings of: the colloquial names of other nationalities, the Russian regional names, and the published articles with illustrations of the species. In this last case, complete information is given on the publications and on the nature of the illustrations. The number of these publications mentioned for each species varies from a couple to over fifty. The further and more elaborate paragraphs on each species have such headings as: diagnosis, additional description, geographical distribution, general characteristics and habits, habitat, burrow and nest, reproduction, molt, enemies, parasites, harm and benefits, and others.

The format of the recent volumes is generally the same as that of the earlier ones, but there have been some qualitative improvements. The clearness of the illustrations has been improved and the emphasis has been placed on an abundance of distinct, well-reproduced drawings of morphological features. Most of the drawings are the author's, but there are many from other sources too. The colored plates were done by V. A. Vatagin, N. N. Kondakov, and A. N. Formozov, and are instructive as well as attractive. However, their reproduction is not as good in the earlier volumes as in the last two. The range maps are detailed and well executed, in most instances providing the individual locality records for the species concerned rather than just the inferred limits of the ranges. The back and covers are more robust and more handsomely composed than those of the earlier volumes.

In the preface of volume VI Professor Ognev states that the entire monograph on the mammals of Russia will comprise twelve volumes and that the ninth volume (Cetaceans) will be done by A. G. Tomilin and the tenth (Ungulates—sheep and goats) by V. I. Tsalkin. This series should surely provide a magnificent basis and inspiration for further study of the paleartic mammals. It is earnestly hoped that the forthcoming volumes will maintain the objectivity and high standards which characterize those published so far.—W. B. Quay. *Museum of Zoology, Univ. of Michigan, Ann Arbor.*

Booth, Ernest S. How to Know the Mammals. William C. Brown Company, Dubuque, Iowa. Pp. 206, 415 figs. 1949. Price, Spiral bound, $2.00; Cloth, $3.00.

The appearance of a manual for the identification of the mammals of North America, especially one designed for the use of non-professionals, would naturally be hailed by teachers of mammalogy. With a copy of Booth's book in hand one can almost be convinced that this is the answer to a prayer for a laboratory and field manual for North American mammal identification.

In one's initial enthusiasm one can be reconciled to the brief treatments of adaptation, biological phenomena, and economic importance for the reason that these considerations are beyond the intended scope of the manual and are adequately dealt with in other books. One reads with interest and approval the section on the preparation of study skins and muses upon the contributions to our knowledge which could be made by a fair-sized body of amateur collectors and preparators distributed over the continent, even if they never identified a specimen or wrote a research paper.

One comes then to the keys and, while reading them with an eye to their usefulness in teaching a college class, one is rudely shocked on page 40 to find elephants and hippopotamuses included in Perissodactyla, and Primates spelled "Primata." But, one says, these are perhaps minor errors when considered in the light of the book's potential usefulness and can easily be corrected to one's class. The discussion may even reinforce the facts in the students' minds. That they are not *lapsus calami* is verified on page 192 where the errors are repeated.

Paging rapidly through the book one may deplore the use, on page 162, of the term "cat" applied to the Ring-tail and regret that authors do not use Ring-tail or Bassarisk to avoid the implications of the word "cat." Particularly does one regret that we have here a contribution to the perpetuation of the doubly-misleading "civet cat."

Directing attention to the distribution maps one finds that they are not accurate for the state of Colorado, and do not indicate that certain mammals which are common in Colorado are to be found there at all. But, after all, Colorado students will have access to Warren's book and can, if they wish, pencil in corrections in their copy of Booth. There remains, however, a nagging doubt whether the maps may be equally erroneous for other areas, but one does not take the time to check, and besides, the maps do show in a general way the distributions of the North American species and if one desires detailed range information he will not depend upon a map of this scale anyway!

One has just about concluded that the manual may be useful for one's purpose when he comes upon the statement, on page 170, that the Black-footed Ferret is an imported animal!

This is the kind of error which is difficult to excuse to a class of adults. My experience with college students suggests that when such an outright error is pointed out to them (as it must be at the earliest opportunity) the recollection of the author's fallibility will remain with them for a long time.

Perhaps this is a good thing and will help to develop in them a healthy sceptical attitude toward all scientific writing, but in a manual for teaching purposes one must necessarily place a considerable confidence in the author. There is some question whether the pedagogical value of the manual may not be decreased by the psychological insecurity engendered by these obvious errors, on the presumption that if there are errors in such elementary matters as those we have mentioned, must there not be similar errors in the more subtle and less obvious portions?—Hugo G. Rodeck, *University of Colorado Museum, Boulder, Colorado.*

McCabe, Thomas T., and Barbara D. Blanchard. Three Species of Peromyscus. Santa Barbara: Rood Associates, Publishers. v + 136, figs. 32. 1950. Price $2.00. (Obtainable from the junior author, Santa Barbara College, University of California, Santa Barbara, California.)

For all its antiquity, natural history remains a remarkably loosely-organized science. For centuries it consisted largely of scattered observations and anecdotes. Even today, university and college courses in the subject are all too frequently composed of assorted details of anatomy, physiology, geography, and behavior, and place a premium upon the recognition of local flora and fauna rather than upon a thorough understanding and appreciation of the ways in which organisms are adapted for survival in a complex environment. There are, however, occasional encouraging signs that this field of inquiry is maturing and that it is gradually taking its proper place as one of the more significant branches of biology. Every now and again the annals of natural history are enriched by a particularly illuminating study of the life of some plant or animal, a study in which keenness of insight combines with precision of observation to provide a really penetrating analysis. An excellent example of this sort of contribution is found in the paper under review. Prepared for publication after the death of the senior author, this comparative ecological investigation of three species of the well-known genus *Peromyscus* was designed to throw light upon such basic problems as the relationship of habitat distribution to population density and the mechanics involved in the regulation of animal numbers. This exceedingly difficult task has been accomplished with notable success. The extensive experience of both authors with these small mammals in the field and in the laboratory, and their exceptional feeling for the manifold complexities of the peromyscan world, have enabled them to achieve an unusually vivid description of the manner in which deer mice are adjusted to their surroundings.

This study is based primarily upon an intensive live-trapping investigation, from 1942 to 1945 inclusive, of natural aggregations of *P. maniculatus*, *P. truei*, and *P. californicus*, found in close association along the interfaces of chaparral and adjoining communities near San Francisco Bay, California. Much valuable information was also secured from breeding colonies maintained in outdoor cages and from wild-caught specimens sacrificed for histological examination. The material obtained from these sources has been presented under ten headings, as follows: General Environment; The Peromyscus Habitat; Habit and Ecology; The Sexual Cycle; Comparative Post-Natal Development; Growth; The Molts;

Temperament; The Rudiments of Territorial Behavior; Population, Longevity and Reproductive Cycle. Though at first sight these subjects may appear somewhat heterogeneous, each is treated as a facet of one compound problem, namely that of the interaction between animal and environment, which forms a strong thread of continuity running throughout the entire work.

Despite the intimacy of association between these three species of *Peromyscus*, each is shown to be unique in many respects. *Maniculatus*, the smallest of the three, is described as temperamentally passive, not easily disturbed nor generally pugnacious, possessed of a comparatively high reproduction potential and apparently endowed with a wide environmental tolerance, though preferring a ground surface well supplied with natural holes and crevices and little inclined to use arboreal pathways. In contrast is the large *californicus*, at birth developmentally much in advance of the other two species, highly specialized with respect to shelter requirements by virtue of its habit of building intricate nest-houses, relatively lacking in pugnacity and resourcefulness (perhaps because of its singular mode of life), having a low reproductive capacity and a comparatively long life span, and living in perceptibly smaller aggregations. *Truei* completes the triangle, for it is intermediate in size, highly active, audacious and brilliant in defense, a frequent climber and jumper, not given to elaborate nest construction yet rarely taking refuge in earth holes. The similarities and differences among these mice have been pictured with considerable skill and ingenuity and offer a convincing explanation for the co-existence of three species of one genus in the same community.

Ecologically inclined mammalogists will be especially drawn by the authors' interpretation of the natural control of deer mouse populations. In a competently handled treatment of the application of Huxley's heterogonic equation and of Robertson's autocatalytic hypothesis to data secured from *Peromyscus*, McCabe and Blanchard find the analogy that has often been drawn between cellular growth and that of populations of organisms an exceedingly questionable one so far as the higher vertebrates are concerned. In the mouse populations under study, none of the usual alleged factors of control, such as transmissible disease, predation, or exhaustion of food supply, seemed to be a uniformly effective regulatory mechanism. (One of the many interesting sidelights of this work was the spectacular destruction of a local population of mice by a series of weasel raids, suggesting that predation pressure may not always be a more or less constant factor but may sometimes descend with sudden and catastrophic force.) Rather, the underlying limiting factor seemed to be the striking discontinuity of the peromyscan habitat. The authors suggest, as a "law of environmental specificity," that limitation of numbers is often effected in higher animals by extraordinarily precise requirements for specific factors in their surroundings, which in the case of *Peromyscus* far exceed "the human observer's power of detection." In these mice, the law appears to operate through a mild territorial intolerance on the part of established individuals and through the eventual elimination by exhaustion and death of those which fail to achieve more than transient status. However intellectually dissatisfying such a recourse to a subtle and seemingly unverifiable process may prove to be, the concept is a challenging one and in many ways more realistic than other more commonly accepted explanations. A similar approach is evident in Dymond's recent hypothesis (Trans. Royal Soc. Canada 41 (5): 1–34, 1947) that the homogeneous nature of the boreal environment is conducive to the production of cyclical fluctuations in populations of northern birds and mammals.

In view of the merits of this study, the few minor imperfections that were noted seem picayune indeed. There are occasional misspelled words, typographical errors, and inconsistencies in the use of symbols. The maximum movement observed in the live-trapping is recorded on p. 100 as 1300 yards, but seems to have increased to 1400 by p. 135. The exact locations of the study areas might well have been given, and more information about numbers of traps used in the various habitats would help the reader to evaluate the results obtained from trapping, for on this data rests the validity of the main argument. Some may cavil at the poetic license which crops up from time to time, now in the alteration of a scientific

name, now in a slightly over-extreme statement. But these are trifles, completely lost in the overall impression of a brilliant style. "Three Species of Peromyscus" is a demonstration of natural history reporting at its very best.—Francis C. Evans. *University of Michigan, Ann Arbor.*

Tanaka, Ryô. A Comparative Study on Formosan Common Rats and Mice of Four Species Belonging to the Genera *Rattus*, *Apodemus* and *Mus* From the Standpoint of Variation-Statistics. 1951. Microfilm copies available for $1.00 each postpaid from Lee R. Dice, Institute of Human Biology, 1135 E. Catherine Street, Ann Arbor, Michigan.

As the author states at the outset, "This paper is the English version with some revision of an article published in the Memoirs of the Faculty of Science, Taihoku Imperial University, Series II, Vol. I, No. 2, pp. 65–118, July, 1944." In addition, it is a summary of several of the author's previous papers dealing with the same species. The English is frequently not idiomatic, but only in a few instances did the reviewer encounter passages which were difficult to understand. The figures are inferior to those in the Japanese edition. There may be difficulty in interpreting some of them.

The species considered, mostly from northern Formosa, are: *Rattus losea* (Swinhoe), *Apodemus agrarius* (Pallas), *Mus formosanus* Kuroda, and *M. musculus L.* Tanaka considers that the first two names have been allocated satisfactorily, but states that the latter two names have been adopted for sake of convenience, since the nomenclatorial status of the genus *Mus* is not clear. Presented in order are comparisons between these four species and discussion of variation in pelage characters, external measurements, skull measurements, and molar attributes, followed by a section on systematic considerations. The original measurements for the two species of *Mus* are given in detail in one of the earlier papers (in English), based on about 100 skins with external measurements and about 60 skulls with measurements for each species. Another paper does the same for *Apodemus* with the data presented by means of reasonably small size classes. In a Japanese publication with tables and summary in German there is a small amount of data on *Rattus*. Apparently there are many additional data in the present paper on the last genus that have not been published elsewhere.

Three different types of hairs are described and age and seasonal variation in them are studied. The coloration was measured with a modified Ives tint-photometer after the manner described by Sumner. The external measurements have been analyzed by means of linear regressions of tail, ear, and foot on body length, using logarithms of the measurements for both axes. Here Tanaka finds that *Rattus* requires no less than three line segments to fit the data and that the others require two segments each. Where such breaks occur in the data, there are approximate methods available to locate them, but there is no unique solution for such problems. This method of fitting separate straight lines to one group of data has been frequently criticized. The reviewer thinks that it would have been better either to make use of curvilinear regression, or else seek some transformation that would make the data amenable to linear regression theory. In some of Tanaka's graphs the angle at the break is indeed very nearly straight. Where the data are actually curvilinear, the greater the range of the independent variate (body length or skull length) the greater the number of separate lines that would be required to give a reasonable fit. It is of interest to note that *Rattus*, by far the largest form here treated, requires more line segments than do the others in order to give a reasonable fit.

One other point of criticism should be mentioned. When one measurement is essentially the sum of two others, such as total skull length being cranial length plus facial length, it is customary to plot facial against cranial length, or vice versa, rather than either of them against total length. Tanaka attempts to show that this is not necessary, and that it is legitimate to plot a part against the whole. His proof is not convincing. In fact, if there were a perfect correlation between the parts, then it would not matter how the data were plotted. If the correlation between the parts were zero, then the correlation between the whole and one of its parts would be expected to be 0.71 on the average. Thus the reliability of any

regression of a part on its whole is related to the correlation between the parts. In these data we may suspect that on the whole the correlations between parts are reasonably high, and so the results are not appreciably vitiated. In addition, most of the measurements are compared against some base of which they are not a part. This matter, however, is one which future workers should take into account.

Aside from these seeming flaws, the treatment is admirable. Of interest to systematists are Tanaka's conclusions that comparable regressions of different forms showing similar slopes and positions are indicative of little or no genetic differences between the forms, except perhaps those which affect total size. Those regressions which differ in some manner may be presumed to represent genetic differentiation which has led to morphological distinctness. The agreement of these conclusions with the commonly accepted notions of relationships is generally good. Thus *Rattus* is shown to be more closely related to *Mus* than to *Apodemus*.

The general aspect of this paper is highly satisfactory. It represents an approach which the reviewer feels could be utilized to a greater extent than at present in systematics. An old axiom of statistical treatment is that the amount of work required to extract the most from the data available is small in relation to the enormous labor involved in collecting and in measuring the specimens. Anyone who spends arduous hours in the field to assemble material should get the greatest results possible from his labors. The methods used by Tanaka represent a step forward that should be investigated by all those interested in systematics and phylogeny.—WILLIAM B. MCINTOSH, *Institute of Human Biology*.

Bourlière, F. VIE ET MOUEURS DES MAMMIFERES. Payot, Paris, 249 pp. 8 pl., 69 figs. 1951. Price 900 fr. = @ $2.50 at current exchange.

In a substantial report on the habits of world mammals, Dr. Bourlière has made a significant contribution. While little is new, the compendium of facts have been well arranged and presented. The volume is divided into ten chapters, treating of locomotion, food, shelter and territory, defense and protection, sexual life and reproduction, development and longevity, migration, social life, distribution and the anatomy and physiology of wild mammals.

Each chapter is well documented, with relevant literature, indicating a serious attempt to cover the pertinent literature in the wide field which is treated. Dr. Bourlière draws freely on the literature of American mammalogy, referring constantly to the pages of the Journal of Mammalogy. He is certainly apprised of the fine work in his own country and credits repeatedly the studies of English, Germans, and South Americans.

The figures are not alone illustrations; each contributes materially to the text. For the biologist who has only a meager knowledge of French, the illustrations alone will serve to improve his knowledge of mammals. All of these are designed to introduce certain aspects of mammalian life that can be understood without reference to the text.

Minor faults are apparent in any great effort. As an example, the gestation of several genera (some of which are not actually known) are faulty. Among these one might cite *Sorex*, *Talpa*, *Gulo*, etc. The matter of communication (Chapter 8) is little understood, yet Bourlière presumably accepts many statements made by those who do not know nor understand wild animals. On these matters, do any of us? The cover depicts a skunk, although a cosmopolite or even the little "herisson" of France would seem more appropriate for the next printing. Fig. 53, showing a female *Sorex araneus* toting the young attached tail to tail, presumably was figured first by Wählstrom, not Schröder and Schöenichen. It is an illustration that many of us have debated. This unique technique is illustrative of the many interesting and yet hardly known methods employed in reproductive behavior.

Bourlière's book ranks with Cabrera's admirable "Manual de Mastozoologia." Any serious student of mammals must have these two works on his shelf as a ready reference.—W. J. HAMILTON, JR. *Cornell University*.

RECENT LITERATURE

(Conducted by G. S. Miller, Jr., Emma Charters, D. H. Johnson, and R. H. Manville)

[Reprints of this section may be purchased from the Corresponding Secretary]

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COMMENTS AND NEWS

HONORARIA FOR YOUNG MAMMALOGISTS

The American Society of Mammalogists will grant annually up to four honoraria of fifty dollars ($50.00) each to young mammalogists (students) for papers to be presented at the annual meeting (see Jour. Mamm., 32: 387).

Papers submitted for the award for 1952 must be in the hands of the Committee on Awards, George H. H. Tate, Stanley P. Young, and William H. Burt, *Chairman*, before *February 1, 1952*. Manuscripts should be sent to the chairman of the committee.

NOTICE OF ANNUAL MEETING

The thirty-second annual meeting of the American Society of Mammalogists will be held at Charleston, South Carolina, probably in April, 1952. Further details will appear in the February issue.

1952 DUES NOW PAYABLE

Pay your 1952 dues now and receive the Journal without interruption. This will also save your Society money. Do not delay, it costs no more to pay dues on time.

AT WHAT DISTANCE CAN A FLYING BAT PERCEIVE SMALL OBJECTS?

In connection with current studies of the use of ultrasonic sounds by flying bats we have been interested in learning whether or not bats detect insect prey by means of echoes of their own pulses of sound. It is certainly reasonable to assume that they do, since their avoidance of small inanimate objects is so clearly based on this natural analogy to radar or sonar instruments (see Jour. Expl. Zool., 86: 481, 1941; or Sci. Amer., Aug., 1950). When *Myotis l. lucifugus* and *Eptesicus f. fuscus* execute their characteristic sudden turns and dives during natural feeding periods there is a clear increase in the number of pulses emitted per second. This also occurs when a pebble is thrown into the air near the flying bat and it turns towards it to investigate. This response of flying bats to almost any small missile is well known and from time to time it must have been observed by many readers of this Journal. If bats do locate pebbles and insects by means of echoes, it becomes important to know at what range an object of a given size and composition can be detected.

In order to supplement our own studies I should like to appeal to others who have observed this type of behavior in bats of various species under a wider range of conditions. The essential question is the distance between a bat and any solid object at which the animal can detect, and turn towards, the missile. Other pertinent facts about such observations are the species of bat, the size and nature of the object perceived, the type of situation (over water, in woods, etc.), and background noise and light conditions (very dark,

near a noisy waterfall, etc.). Descriptions of any type of bat behavior in which objects are perceived at a distance will be of interest in this connection. Due acknowledgement will of course be made if any such reports are used in future publications.—

DONALD R. GRIFFIN,
Department of Zoology,
Cornell University,
Ithaca, New York.

DEATHS

Recent deaths reported are: **Sherman C. Bishop,** Rochester, N. Y., May 28, 1951; **J. Southgate Y. Hoyt,** Ithaca, N. Y., June 1, 1951.

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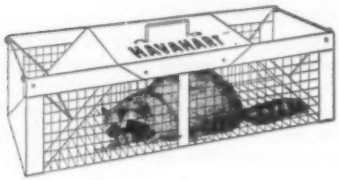

Live traps for SMALL MAMMALS, as well as those for mammals as large as a raccoon, are now available from the *Allcock Manufacturing Company, Ossining. New York.* HAVAHART traps have been used successfully by many who have been doing live-trapping experiments on small mammals. A free booklet is yours for the asking.

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